90-603

Evaluation of Neural Network Performance in Target Classification Applications

Prepared for

DREO

by

W.E. Thorp Associates Ltd.

December, 1989

THORP ASSOCIATES

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TABLE OF CONTENTS

1. INTRODUCTION 1

1.1 Purpose 1
1.2 Scope 1

2. EVALUATION 2

2.1 Evaluation Goals 2
2.2 General Methodology 2
2.3 Network Selection 8
2.4 Performance Summary 8

3. CONCLUSIONS 11

3.1 Evaluation as Target Classifier 11
3.2 Further Studies 11
3.3 Other Applications 13

4. REFERENCES 15

LIST OF TABLES

Table 2.1 - Available Networks 4
Table 2.2 - Performance Summary (Non-Random Training Data and Random Test Data) . 9
Table 2.3 - Performance Summary (Random Training Data and Random Test Data) . 10
Table 2.4 - Performance Summary (Translated, Scaled, etc., Test Data) 10
Table 4.1 - Contents of NeuralWare Documentation Package 15

LIST OF FIGURES

Figure 2.1 - System Overview 5
Figure B.2.1 Example Image with 3 Added and/or Modified Peaks 59
Figure B.2.2 Example Image with 6 Added and/or Modified Peaks 60
Figure B.2.3 Example Image with 9 Added and/or Modified Peaks 61
Figure B.2.4 Example Image with 12 Added and/or Modified Peaks 62
Figure B.2.5 Example Image with 48 Added and/or Modified Peaks 63
Figure B.2.6 Example Image with 81 Added and/or Modified Peaks 64

TABLE OF CONTENTS

APPENDICES

A. EXPERIMENTS 16

A.1 Experiment 1 - Adaline Network 16
A.2 Experiment 2 - Hamming Network 20
A.3 Experiment 3 - BAM Network 23
A.4 Experiment 4 - Recirculation Network......... 27
A.5 Experiment 5 - Back Propagation Network 32
A.6 Experiment 6 - Adaline Network (Random Training 12 Peaks) .. 37
A.7 Experiment 7 - Adaline Network (Random Training 24 Peaks) .. 40
A.8 Experiment 8 - Back Propagation Network (Random Training 24 Peaks) .. 43
A.9 Experiment 9 - Test Performance with Scaled, Translated, etc. Images 47

B. DATA CREATION 50

B.1 Image File 50
B.1.2 Image File Format 53
B.2 Neural Network Input Files 58
B.2.1 Files for Binary/Bipolar Networks.......... 65
B.2.2 Files for Continuous Networks 65

C. NETWORK LISTINGS 66

C.1 Adaline Network 66
C.2 Hamming Network 67
C.3 BAM Network 68
C.4 Recirculation Network 69
C.5 Back Propagation Network 70

TABLE OF CONTENTS

APPENDICES

D. COMPUTER LOGS 71

D.1 Adaline Network 71
D.1.1 Data Generation Logs (Training Files) 71
D.1.2 Data Generation Logs (Testing Files) 76
D.1.3 Test Results Logs 80
D.2 Hamming Network 100
D.2.1 Data Generation Logs (Training Files) 100
D.2.2 Data Generation Logs (Testing Files) and Test Results Logs 101
D.3 BAM Network 112
D.3.1 Data Generation Logs (Training Files) 112
D.3.2 Data Generation Logs (Testing Files) and Test Results Logs 113
D.3.3 Data Generation Logs (Training Files) Small Test File 117
D.3.4 Data Generation Logs (Testing Files) and Test Results Logs for Small Test File . 118
D.4 Recirculation Network 120
D.4.1 Data Generation Logs (Training Files) 120
D.4.2 Data Generation Logs (Testing Files) 125
D.4.3 Test Results Logs 129
D.5 Back Propagation Network 155
D.5.1 Data Generation Logs (Training Files) 155
D.5.2 Data Generation Logs (Testing Files) 160
D.5.3 Test Results Logs 164
D.6 Adaline Network Random Training (12 Peaks) . 185
D.6.1 Data Generation Logs (Training Files) 185
D.6.2 Test Results Logs 190
D.7 Adaline Network Random Training (24 Peaks) . 194
D.7.1 Data Generation Logs (Training Files) 194
D.7.2 Test Results Logs 199
D.8 Back Propagation Network Random Training (24 Peaks) 202
D.8.1 Data Generation Logs (Training Files) 202
D.8.2 Test Results Logs 207
D.9 Neural Network Performance with Translated, Scaled, etc. Images 212
D.9.1 Data Generation and Test Results Logs 212

E. PROGRAM LISTINGS 219

1. INTRODUCTION

1.1 Purpose

The purpose of this report is to document the evaluation of the suitability of neural networks for target classification.

1.2 Scope

The scope of this evaluation is extremely limited since contract funding was minimal. The overall goal of the contract is to establish that neural networks can be used as target classifiers in the presence of noise. Although the application of neural networks to the operational scenario is discussed, the evaluation was done using very simple models.

The experimental results included in this report go beyond that needed to establish whether neural networks are suitable for this application. The experimental data could be further analyzed at a later date to give insight into why a particular network was suitable or not, how the network learned to perform its function, etc.

Two programs were written to support the operation of the neuralware software package. Since the emphasis is on the experimental results and not software development, the documentation for the programs is only sufficient to allow the implementor to run or maintain the programs.

2. EVALUATION

This section provides an overview of the experiments carried out to perform the evaluation. Detailed descriptions of the actual experiments are contained in the appendices.

2.1 Evaluation Goals

The detailed goals of the evaluation are as follows:

(a) evaluate the capability of neural networks to correctly classify one of ten targets. The targets are represented as 2D images on a grid of pixels. The pixels contain variable intensities. The test images will be the same images used during training without any noise added.

(b) evaluate the capability of neural networks to correctly classify one of ten targets using the same representation as in (a). However, the test images will contain extra peaks or changed peaks. The pixels selected for the addition or modification of peaks and the magnitude of the change or addition will be random.

(c) evaluate the capability of neural networks to correctly classify one of ten targets using the same representation as in (a). Train the networks with images which contain extra peaks or modified peaks. The test images will be the same images used for testing in (a) and (b) above.

(d) evaluate the capability of neural networks to recognize an image which has been translated, scaled, etc. One image was selected from the training set and modified. Previously trained networks were tested using the translated, scaled, etc. images.

2.2 General Methodology

In order to perform the evaluation in the limited time available, a commercial software package was purchased. This package contains eleven different neural networks. Although it is possible to create custom networks using this software, this was not done. Instead, a feature of the software called Instanet was used for network creation. This feature allows the creation of the eleven standard networks supplied with the software package.

A summary of the available networks and their main features is listed in the table 2.1. The table entries are specific to the network implementation in the software package. For example, the Adaptive Resonance Theory network also has a continuous version. However, the software package only provides a binary version.

Even though a commercial package was used to create the neural networks, it was still necessary to write two programs. An overview of the complete system is shown in figure 2.1. Comments giving additional explanations about figure 2.1 follow the figure. The comments are numbered to correspond to the numbered boxes in figure 2.1.

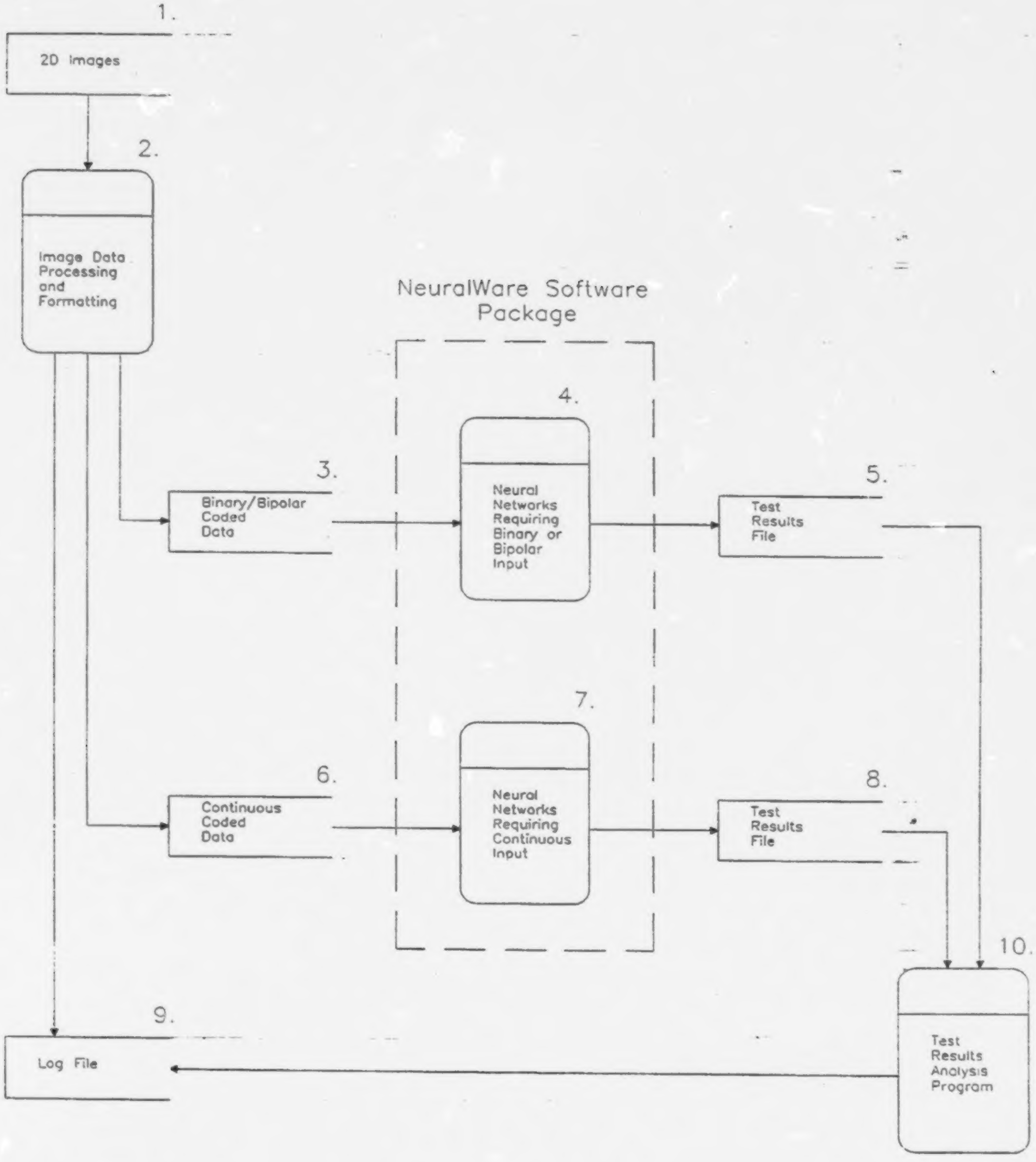
2. EVALUATION 2.

Table 2.1 - Available Networks

Name	Type	Input	Learning
Perceptron	Heteroassociative	Binary	Supervised
Adaline Madaline	Heteroassociative Heteroassociative	Bipolar Bipolar	Supervised Supervised
Brain State in a Box	Autoassociative	Bipolar	Supervised
Hopfield	Autoassociative	Binary	Supervised
Back Propagation	Autoassociative or Heteroassociative	Continuous	Supervised
Counter Propagation	Heteroassociative	Continuous	Unsupervised
Bidirectional Associative Memory	Heteroassociative	Bipolar	Supervised
Spatial Temporal Pattern Recognition	Heteroassociative?	Continuous?	Unsupervised
Hamming	Heteroassociative	Bipolar	Supervised
Adaptive Resonance Theory		Binary	Unsupervised
Recirculation Network	Autoassociative	Continuous	Supervised

2. EVALUATION 2.

Figure 2.1 - System Overview


1.
2D Images
2.
Image Data Processing and Formatting
NeuralWare Software Package
3.
Binary/Bipolar Coded Data
4.
Neural Networks Requiring Binary or Bipolar Input
5.
Test Results File
6.
Continuous Coded Data
7.
Neural Networks Requiring Continuous Input
8.
Test Results File
9.
Log File
10.
Test Results Analysis Program

2. EVALUATION 2.

Comments on Figure 2.1

1. A file of 2D images was created using an editor. Each image consisted of 6 rows of 27 columns.

2. This image file is read into a program. The program performs the following functions:

   (a) optionally add more peaks or modify peaks already in the image
   (b) optionally add noise to the image
   (c) if the program is creating data for a network which requires continuous input, scale the data to be between 0.0 and 1.0
   (d) if the program is creating data for a network which requires binary or bipolar input, the image is converted into a form which uses linearly separable coding
   (e) write the data to a disc file. Since the behaviour of a network is affected by the order of the presentation of the training data, the program may optionally randomize the data records as they are written to the file and create multiple data sets.
   (f) output program parameters to log file.

   See appendix B for more details on data set creation.

3. Files used for training or testing binary networks consist of zeros and ones. Files used for training and testing bipolar networks consist of minus ones and plus ones.

4. The data files are read by the neural network software package. The networks are trained. Training may consist of a one shot process where the weights are set according to some fixed algorithm (e.g. BAM and Hamming) or may consist of repeated presentation of training data sets. After the networks are trained, they are tested. The network produces a file of results.

5. The results file consists of a record for each test image. The format of the records is described in reference [2], page 281.

6. Files used for training or testing continuous networks consist of values scaled to be in the range 0.0 to 1.0.

7. The data files are read by the neural network software package. The networks are trained. Training consists of repeated presentation of training data sets. After the networks are trained, they are tested. The network produces a file of results.

2. EVALUATION 2.

8. The results file consists of a record for each test image. The format of the records is described in reference [2], page 281.

9. An analysis program reads the input data file containing the expected results and the results file containing the actual results. It compares the actual and expected results and may optionally display all actual and expected values in several different formats. The results are also written to a log file.

10. The log file records the parameters used for generation of the training and test data and the results of network tests. (See appendices B and D).

2. EVALUATION 2.

2.3 Network Selection

In order to evaluate the performance of neural networks using the pixel representation of the target data, it is sufficient to select either a heteroassociative or autoassociative network which uses supervised learning. The network can be either binary or continuous. Further, the network should be able to learn arbitrary patterns and not be limited to linearly separable patterns.

Thus, the following binary/bipolar networks were evaluated: Adaline, Bidirectional Associative Memory (BAM), and Hamming. The Perceptron was not chosen because it requires orthogonal inputs. The Hopfield network was not chosen because the Hamming network provides a heteroassociative extension to the Hopfield network which offers superior performance and requires many fewer connections. In particular, the Hopfield network required more connections than the commercial neural network software package supported. The Brain-state-in-a-Box was not chosen because it required more memory for connections that was available on the computer that was being used for simulations.

Further, the following continuous networks were evaluated: Back Propagation and recirculation.

2.4 Performance Summary

Table 2.2 summarizes the performance of the various networks when trained on images that contained no additional and/or modified peaks and tested with images that contained additional and/or modified peaks.

Table 2.3 summarizes the performance of the various networks when trained on images that contained additional and/or modified peaks.

Table 2.4 summarizes the performance of the various networks when tested with an image from the original training set that was translated, scaled, etc.

2. EVALUATION 2.

Table 2.2 - Performance Summary (Non-Random Training Data and Random Test Data)

Network	Number of Added or Modified Peaks (Test Data)	Performance
Adaline	0	100.0%
	3	100.0%
	6	95.0%
	9	82.3%
	12	71.0%
Hamming	0	100.0%
	3	100.0%
	6	100.0%
	9	100.0%
	12	100.0%
	48	99.7%
	65	100.0%
	81	98.7%
	100	93.7%
	125	68.0%
BAM	0	30.0%
	3	46.3%
	6	not tested
	9	not tested
	12	0.0%
Recirculation	0	100.0%
	3	98.3%
	6	95.3%
	9	87.0%
	12	81.3%
Back Propagation	0	100.0%
	3	89.7%
	6	79.3%
	9	73.0%
	12	62.3%

Table 2.3 - Performance Summary (Random Training Data and Random Test Data)

Network	Number of Added or Modified Peaks (Training Data)	Number of Added or Modified Peaks (Test Data)	Performance
Adaline	12	0	100.0%
		3	100.0%
		6	98.7%
		9	95.0%
		12	90.7%
Adaline	24	0	100.0%
		3	100.0%
		6	99.7%
		9	97.7%
		12	96.3%
Back Propagation	24	0	60.0%
		3	60.0%
		6	59.3%
		9	59.7%
		12	59.7%

Table 2.4 - Performance Summary (Translated Scaled, etc., Test Data)

Network	Performance
Adaline	8.3%
Hamming	58.3%
Recirculation	0.0%
Back Propagation	16.7%

3. CONCLUSIONS

3.1 Evaluation as Target Classifier

The Adaline network performed well. It was able to classify the images when trained using images without any additional and/or modified peaks. It was the only network whose performance improved when it was trained using images with additional and/or modified peaks. This network did not perform well on test images that were translated, scaled, etc.

The Hamming network provided the best performance of any network tested. It was able to classify the images correctly 100% of the time even when tested on images with a large number of additional and/or modified peaks. It also had the best performance on test images that were translated, scaled, etc.

The BAM network was unable to classify the images.

The recirculation network performed well when trained using images without additional and/or modified peaks. The network was not trained using images with additional and/or modified peaks. The network did not perform well on test images that were translated, scaled, etc.

The back propagation network performed well when trained using images without any additional and/or modified peaks and when tested on images with only a few (i.e. 3 or less) additional and/or modified peaks. It did not perform well when trained using data with additional and/or modified peaks. It also did not perform well when tested with images that were translated, scaled, etc.

3.2 Further Studies

This evaluation has provided a very simple evaluation which is far removed from the actual operational requirements. In order to evaluate the performance of neural networks under actual operational conditions, it will be necessary to expand the scope of study in a number of ways.

3.2.1 Investigate Intelligent Preprocessing and Feature Extraction and Representation

The simple model of using pixels for the feature representation should be investigated to provide a more optimal set of features. For example, the following feature representations could be investigated:

(a) take only some subset of the pixels which are above a threshold value and use their location and intensity as features

(b) compress the image by some value and use the compressed pixel representation as the features (i.e. if the image was compressed by 8, then each 8 by 8 block of pixels is compressed to one pixel by adding all the values and dividing by 64)

(c) more sophisticated feature representations using moments or FFTs. The use of these feature extraction techniques would increase network performance on images that were translated, scaled, etc.

3.2.2 Investigate Generalization Capabilities

It has been shown that there is a relationship between how well a network generalizes and the ratio of the number of weights in the network to the number of training cases, i.e. if the number of training cases is much greater than the number of weights, then the network will generalize well.

In our evaluation, there were a large number of weights and a limited amount of training data. Thus, it is likely that the networks that were trained using repeated presentations of the images (i.e. Adaline, recirculation and back propagation) learned to classify the images by doing a table look up (i.e. they memorized the images rather than learning to recognize characteristics of the images).

3.2.3 Investigate Problems When More Images to be Classified

Although most networks performed well on this simple problem, they may have trouble when there are more images which must be classified. For example, the Hamming network has an upper limit on the number of images which can be classified. The number of exemplars which can be stored in the network is given by M*(M+N) where M is the number of elements in the category layer and N is the number of elements in the input layer. The relative performance of the various networks may change when more images must be classified.

3.2.4 Investigate Different Network Parameters

The performance of the networks that require repeated presentations of images is affected by a number of parameters, e.g. learning rate. The default values supplied by the Neuralware software package were used during training and testing. It is likely better performance can be obtained by adjusting these parameters.

3.2.5 Investigate Different Network Architectures

Only one configuration of the back propagation network was studied. There is a great deal of interest in these networks with much work being done to improve speed and performance. Further study should be done on these networks using different numbers of layers and different numbers of hidden elements per layer.

None of the networks performed well on images that were translated, scaled, etc. Network architectures exist which can handle translated, scaled, etc. images. These networks are similar to the neocognitron and have constrained weights and multiple hidden layers.

3.2.6 Investigate Other Networks

Not all types of networks were available in the Neuralware software package. For example, Boltzmann machines and Kohonen feature maps were not available. Also, many newer networks have been developed which are not available in the package.

3.2.7 Investigate Methods for Creating Training Libraries

In order to classify targets of interest, it will be necessary to build up a library of targets which can be used for comparison. It is likely that the library will have to contain targets at different orientations since the orientation significantly impacts the target features. Work would have to be carried out on determining how many orientations are required. Also, the method used for the actual creation of the library will require study. In particular, the library could be formed using one or more of the following methods:

(a) using unsupervised learning to extract the relevant exemplars from real target data
(b) using computer models of the targets to provide target exemplars
(c) using physical models of the targets to provide target exemplars

3.3 Other Applications

Neural networks are potentially applicable to many different aspects of the spotlight SAR project in addition to just target classification. Some of the potential areas where neural networks might be applied are as follows:

(a) Ultimately, it is possible that they could learn to recognize targets using unprocessed SAR data. Many intermediate stages are possible since neural networks can perform signal processing and filtering operations and can learn to calculate arbitrary non-linear equations.

3. CONCLUSIONS 3.

(b) neural networks could be used for any application requiring adaptive control, e.g. to learn characteristics of antenna pointing errors and remove them, filter antenna signals, etc.

(c) motion compensation and correction.

4. REFERENCES

The references for this report are all contained in a single binder provided by NeuralWare. This binder contains user documentation and general background on neural networks plus updates to the documentation. The updates are jumbled together at the back of the binder. The binder contents are given in the table below:

Table 4.1 Contents of NeuralWare Documentation Package

Reference Number	Document
1	An Introduction to Neural Computing, rev. 2.00
2	NeuralWorks Users Guide, rev. 2.00
3	Networks I, rev. 2.00
4	Networks II, rev. 2.00
5	January 1989 errors and additions
6	Users Guide Updates
6(a)	- technical notes section (pages 307-312)
6(b)	- spreadsheet interface (pages 281 -292)
6(c)	- loadable control strategy
6(d)	- neural probe
6(e)	- keyboard I/O
7	Networks III

A. EXPERIMENTS

A.1 Experiment 1 - Adaline Network

Purpose: To evaluate the performance of the Adaline neural network using a pixel representation of the target.

Method: The following steps were performed to analyze the Adaline network performance:

1. The Adaline network was created using the Instanet facility of the NeuralWare software package. The parameters used to create the network were:

   - Input 648 elements
   - Output 10 elements.

   Note, in order to create this network, it is necessary to increase the default maximum number of processing elements which can be allocated by the NeuralWare software. This is done by specifying the following option when starting the software: -v700. This option must also be specified any time the Adaline network is executed.

   In addition to the basic network, the neural probe facility was used to create displays of the input and output layers. The neural probe is disabled during normal network operations but can be re-enabled using the appropriate menu options.

2. Five training files were created using the "nnimag" program. Each file consisted of 30 sets of 10 images (See B.1). The logs of the parameters entered to create the files are included in section D.1.1. The training files are named: AD1.NNI, AD2.NNI, AD3.NNI, AD4.NNI and AD5.NNI.

3. Four test files were created using the "nnimag" program. Each file consisted of 30 sets of 10 images (See B.1). The original images were modified by adding and/or modifying the peaks in the original images. The logs of the parameters entered to create the files are included in section D.1.2. The testing files and the number

of added and/or modified peaks are as follows:

- ADR1.NNI, 3 peaks
- ADR2.NNI, 6 peaks
- ADR3.NNI, 9 peaks
- ADR4.NNI, 12 peaks.

4. The Adaline network created in step 1 was loaded and executed. Training and testing of the network were alternated once the network was able to correctly categorize the data with which it was being trained. The logs from the results analysis program ("nnres") for each set of tests are included in section D.1.3.

5. The trained network has been saved as AD4500.NND.

Results: The results of the training and testing are summarized in the following table.

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	ADR1	ADR2	ADR3	ADR4
302	AD1*	240/300 80.0%				
603	AD2*	300/300 100.0%	271/300 90.3%	222/300 74.0%	180/300 60.0%	161/300 53.7%
904	AD3*	300/300 100.0%	292/300 97.3%	265/300 88.3%	212/300 70.7%	
1205	AD4*	300/300 100.0%	295/300 98.3%	275/300 91.7%	224/300 74.7%	197/300 65.7%
1506	AD5*	300/300 100.0%	300/300 100.0%	280/300 93.3%	240/300 80.0%	199/300 66.3%
2108	AD1 AD3*	300/300 100.0%	300/300 100.0%	283/300 94.3%	246/300 82.0%	208/300 69.3%
2710	AD2 AD1*	300/300 100.0%	300/300 100.0%	285/300 95.0%	246/300 82.0%	211/300 70.3%
3312	AD3 AD5*	300/300 100.0%	300/300 100.0%	285/300 95.0%	247/300 82.3%	212/300 70.7%
3914	AD2 AD4*	300/300 100.0%	300/300 100.0%	285/300 95.0%	247/300 82.3%	213/300 71.0%
4516	AD4 AD5*	300/300 100.0%	300/300 100.0%	285/300 95.0%	247/300 82.3%	213/300 71.0%

* This training file was used to test the network during the testing phase.

Observations: The network appears to converge in about five times as many trials as there are processing elements. This result agrees with that obtained by other experimenters.

It takes approximately 3.5 minutes to execute 300 learning presentations (i.e. LEARN ALL option for a training file) and approximately 2.3 minutes to execute 300 recalls (i.e. RECALL ALL option for a test file). These times are for a 16Mhz 80386 with a 80387 coprocessor running the optimized version of the NeuralWare software (i.e. n2f). The neural probes were disabled.

The Adaline network continues to learn even after it obtains the desired result. Thus, it is possible that further training could result in poorer performance.

Conclusions: The adaline network is able to solve the classification problem when the number of added and/or modified peaks was 6 or less pixels. Note, the number of pixels occupied by peaks in the original images is either 18 or 24 (i.e. 6 images have 3 peaks of 6 pixels each and 4 images have 4 peaks of 6 pixels each). This network should be included in further studies of this classification problem.

A.2 Experiment 2 - Hamming Network

Purpose: To evaluate the performance of the Hamming neural network using a pixel representation of the target.

Method: The following steps were performed to analyze the Hamming network performance:

1. The Hamming network was created using the Instanet facility of the NeuralWare software package. The parameters used to create the network were:

   - Input 648 elements
   - Output 10 elements.

   Note, in order to create this network, it is necessary to increase the default maximum number of processing elements which can be allocated by the NeuralWare software. This is done by specifying the following option when starting the software: -v700. This option must also be specified any time the Hamming network is executed.

   In addition to the basic network, the neural probe facility was used to create displays of the input and output layers. The neural probe is disabled during normal network operations but can be re-enabled using the appropriate menu options.

   The temperature field in the learning/recall schedule should be set to zero. This prevents further randomization of the inputs during recall.

2. One training file was created using the "nnimag" program. This file consisted of 10 images (See B.1). The log of the parameters entered to create the file is included in section D.2.1. The training file is named HAMMING.NNI

3. Four test files were created using the "nnimag" program. Each file consisted of 30 sets of 10 images (See B.1). The original images were modified by adding and/or modifying the peaks in the original images. The logs of the parameters entered to create the files are included in section D.2.2. The testing files and the number of added and/or modified peaks are as follows:

- HAR1.NNI, 3 peaks
- HAR2.NNI, 6 peaks
- HAR3.NNI, 9 peaks
- HAR4.NNI, 12 peaks.

Note, the test files contain exactly the same randomized image data as the test files used for the Adaline test.

4. The Hamming network created in step 1 was loaded and executed. Training the Hamming network is a one shot process (i.e. the training data is presented only once and the weights are adjusted only once). The network was then tested on the training file and the four test files. The logs from the results analysis program ("nnres") for the tests are included in section D.2.2.

5. Since the performance of the Hamming network was very good with low numbers of random peaks, an additional set of five test files was generated with greater numbers of random peaks. Each file consisted of 30 sets of 10 images (See B.1). The original images were modified by adding and/or modifying the peaks in the original images. The logs of the parameters entered to create the files are included in section D.2.2. The testing files and the number of added and/or modified peaks are as follows:

   - HAR5.NNI, 48 peaks
   - HAR6.NNI, 65 peaks
   - HAR7.NNI, 81 peaks
   - HAR8.NNI, 100 peaks
   - HAR9.NNI, 125 peaks.

6. The trained network has been saved as HAM10.NND.

Results: The results of the training and testing are summarized in the following tables.

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	HAR1	HAR2	HAR3	HAR4
10	HAMMING	10/10 100.0%	300/300 100.0%	300/300 100.0%	300/300 100.0%	300/300 100.0%

A. EXPERIMENTS A.

Total Number of Training Images	Training File(s)	Testing Files				
		HAR5	HAR6	HAR7	HAR8	HAR9
10	HAMMING	299/300 97.3%	300/300 100.0%	296/300 98.7%	281/300 93.7%	204/300 68.0%

Observations: It takes approximately 3.0 minutes to execute 300 recalls (i.e. RECALL ALL option for a test file). These times are for a 16Mhz 80386 with a 80387 coprocessor running the optimized version of the NeuralWare software (i.e. n2f). The neural probes were disabled.

Conclusions: The Hamming network is able to solve the classification problem in all cases. This network should be included in further studies of this classification problem.

A.3 Experiment 3 - BAM Network

Purpose: To evaluate the performance of the BAM neural network using a pixel representation of the target.

Method: The following steps were performed to analyze the BAM network performance:

1. The BAM network was created using the Instanet facility of the NeuralWare software package. The parameters used to create the network were:

   - Input 648 elements
   - Output 10 elements.

   Note, in order to create this network, it is necessary to increase the default maximum number of processing elements which can be allocated by the NeuralWare software. This is done by specifying the following option when starting the software: -v1500. This option must also be specified any time the BAM network is executed.

   In addition to the basic network, the neural probe facility was used to create displays of the input and output layers. The neural probe is disabled during normal network operations but can be re-enabled using the appropriate menu options.

2. One training file was created using the "nnimag" program. This file consisted of 10 images (See B.1). The log of the parameters entered to create the file is included in section D.3.1. The training file is named BAM.NNI

3. Two test files were created using the "nnimag" program. Each file consisted of 30 sets of 10 images (See B.1). The original images were modified by adding and/or modifying the peaks in the original images. The logs of the parameters entered to create the files are included in section D.3.2. The testing files and the number of added and/or modified peaks are as follows:

   - BAMR1.NNI, 3 peaks
   - BAMR4.NNI, 12 peaks.

   Note, the test files contain exactly the same randomized image data as the test files used for the Adaline test.

4. The BAM network created in step 1 was loaded and executed. Training the BAM network is a one shot process (i.e. the training data is presented only once and the weights are adjusted only once). The network was then tested on the training file and then the two test files. Because the performance was so poor, testing was carried out using 1 iteration and 20 iterations during the recall stage. The logs from the results analysis program ("nnres") for the tests are included in section D.3.2.

5. In order to ensure that some fundamental error was not being made, a second small BAM network was set up. This network used only 32 inputs and 3 outputs. The network was trained and tested on an image file which contained 3 very different images on an 4 by 2 grid. This image file was run through the "nnimag" program to create a training file consisting of the three images only and a test file consisting of 10 sets of the three images with 3 random peaks added to the original image. The log for the training file is included in section D.3.3 and the logs for the testing files and the results are included in section D.3.4.

Results: The results of the training and testing on the image files are summarized in the following table.

Total Number of Training Images	Training File(s)	Testing Files					
		Training File 20It.	Training File 1It.	HAR1 1 It.	HAR1 20 It.	HAR2 1 It.	HAR2 20 It.
10	BAM	0/10 0.0%	3/10 30.0%	139/300 46.3%	0/300 0.0%	20/300 6.7%	0/300 0.0%

The results obtained using the small BAM network with 20 iterations during recall are as follows:

- training file 3/3 or 100.0%
- test file 54/90 or 60.0%.

Observations: It takes approximately 20 minutes to execute 300 recalls when 20 iterations are used during recall (i.e. RECALL ALL option for a test file). These times are for a 16Mhz 80386 with a 80387 coprocessor running the optimized version of the NeuralWare software (i.e. n2f). The neural probes were disabled.

The BAM network was failing because it always produced one of two patterns after about 5 or 6 iterations during recall. These two patterns were not present in the original image data and thus the correct category was never determined. The two patterns are as follows (See Appendix B.1 for a description of image patterns):

Pattern One

	1				5					10					15					20					25		27
1																											
2																											
3	H	H	H																						H	H	H
4	H	H	H																						H	H	H
5																											
6																											

Pattern Two

	1				5					10					15					20					25		27
1																											
2																											
3	H	H	H																						M	M	M
4	H	H	H																						M	M	M
5																											
6																											

The BAM network should be capable of storing a number of patterns which is equal to the minimum of the number of processing elements in its two layers (i.e. min (648,10) in this case). However, because all of the image patterns are similar, it is not able to correctly recall the images and instead produces image patterns which do not occur in the original data set.

Conclusions: The BAM network is not able to solve this particular classification problem. It should not be considered further if the feature representation used for image classification is the pixel representation. It is possible that the BAM network could be employed if different feature representations were used.

A.4 Experiment 4 - Recirculation Network

Purpose: To evaluate the performance of the recirculation neural network using a pixel representation of the target.

Method: The following steps were performed to analyze the recirculation network performance:

1. The recirculation network was created using the Instanet facility of the NeuralWare software package. The parameters used to create the network were:

   - Input 162 elements
   - Output 162 elements.

   The AUX1 counter controls cumulative weight update intervals and should be set equal to the number of images in the data set, i.e. in this case AUX1 was set to 10. The r and C1 parameters were left set to their default values, i.e. r = .75 and C1 = .1.

   In addition to the basic network, the neural probe facility was used to create displays of the input and output layers. The neural probe is disabled during normal network operations but can be re-enabled using the appropriate menu options.

2. Five training files were created using the "nnimag" program. Each file consisted of 30 sets of 10 images (See B.1). The logs of the parameters entered to create the files are included in section D.4.1. The training files are named: REC1.NNI, REC2.NNI, REC3.NNI, REC4.NNI and REC5.NNI.

3. Four test files were created using the "nnimag" program. Each file consisted of 30 sets of 10 images (See B.1). The original images were modified by adding and/or modifying the peaks in the original images. The logs of the parameters entered to create the files are included in section D.4.2. The testing files and the number of added and/or modified peaks are as follows:

   - RECR1.NNI, 3 peaks
   - RECR2.NNI, 6 peaks
   - RECR3.NNI, 9 peaks
   - RECR4.NNI, 12 peaks.

4. The recirculation network created in step 1 was loaded and executed. Training and testing of the network were alternated once the network was able to correctly categorize the data with which it was being trained. The logs from the results analysis program ("nnres") for each set of tests are included in section D.4.3.

5. The trained network has been saved as REC7500.NND.

Results: The results of the training and testing are summarized in the following table.

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	RECR1	RECR2	RECR3	RECR4
302	REC1* (Tol=.31)	120/300 40.0%				
302	REC1* (Tol=.21)	60/300 20.0%				
603	REC2* (Tol=.31)	210/300 70.0%				
603	REC2* (Tol=.21)	60/300 30.0%				
904	REC3* (Tol=.31)	210/300 70.0%				
904	REC3* (Tol=.21)	90/300 30.0%				
1205	REC4* (Tol=.31)	270/300 90.0%				
1205	REC4* (Tol=.21)	180/300 60.0%				
1506	REC5* (Tol=.31)	270/300 90.0%				
1506	REC5* (Tol=.21)	210/300 70.0%				

A. EXPERIMENTS A.

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	RECR1	RECR2	RECR3	RECR4
1807	REC1* (Tol=.31)	270/300 90.0%				
1807	REC1* (Tol=.21)	270/300 90.0%				
2108	REC3* (Tol=.31)	270/300 90.0%				
2108	REC3* (Tol=.21)	270/300 90.0%				
2409	REC2* (Tol=.31)	300/300 100.0%				
2409	REC2* (Tol=.21)	270/300 90.0%				
2710	REC1* (Tol=.31)	300/300 100.0%				
2710	REC1* (Tol=.21)	270/300 90.0%				
3011	REC3* (Tol=.31)	300/300 100.0%	297/300 99.0%	291/300 97.0%	265/300 88.3%	254/300 84.7%
3011	REC3* (Tol=.21)	300/300 100.0%	270/300 90.0%	226/300 75.3%	187/300 62.3%	173/300 57.7%
3312	REC5* (Tol=.21)	300/300 100.0%				
3613	REC2* (Tol=.21)	300/300 100.0%				
3914	REC4* (Tol=.31)		298/300 99.3%	290/300 96.7%	265/300 88.3%	255/300 85.0%
3914	REC4* (Tol=.21)	300/300 100.0%	279/300 93.0%	230/300 76.7%	194/300 64.7%	179/300 59.7%

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	RECR1	RECR2	RECR3	RECR4
4215	REC4* (Tol=.21)	300/300 100.0%				
4516	REC5* (Tol=.21)	300/300 100.0%				
4817	REC1* (Tol=.31)		297/300 99.0%	289/300 96.3%	263/300 87.7%	249/300 83.0%
4817	REC1* (Tol=.21)	300/300 100.0%	280/300 93.3%	231/300 77.0%	194/300 64.7%	174/300 58.0%
5118	REC2* (Tol=.21)					
5419	REC1* (Tol=.21)					
5720	REC3* (Tol=.21)					
6021	REC4* (Tol=.31)		296/300 98.7%	288/300 96.0%	261/300 87.0%	249/300 83.0%
6021	REC4* (Tol=.21)	300/300 100.0%	279/300 93.0%	227/300 75.7%	192/300 64.0%	164/300 54.7%
6322	REC3* (Tol=.21)					
6623	REC4* (Tol=.21)					
6924	REC5* (Tol=.21)					
7225	REC2* (Tol=.21)					

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	RECR1	RECR2	RECR3	RECR4
7526	REC5* (Tol=.31)		295/300 98.3%	286/300 95.3%	261/300 87.0%	244/300 81.3%
7526	REC5* (Tol=.21)	300/300 100.0%	280/300 93.3%	224/300 74.7%	184/300 61.3%	156/300 52.0%

* This training file was used to test the network during the testing phase.

Observations: It takes approximately 2.5 minutes to execute 300 learning presentations (i.e. LEARN ALL option for a training file) and approximately 3.0 minutes to execute 300 recalls (i.e. RECALL ALL option for a test file). These times are for a 16Mhz 80386 with a 80387 coprocessor running the optimized version of the NeuralWare software (i.e. n2f). The neural probes were disabled.

Other experimenters have noticed that it is possible to overtrain a network when working on classification problems. The slightly poorer performance exhibited by this network as training proceeds may be a manifestation of this phenomena. The network learns the main features needed for classification. However, if training continues, it will then learn other less important features of the targets and thus performance declines.

Equally, since the performance of this type of network is highly dependent on the proper choice of the C1 and r parameters, it could just be that the C1 and r parameters should be adjusted to allow the network to converge further.

Conclusions: The recirculation network is able to solve the classification problem. This network should be included in further studies of this classification problem.

A.5 Experiment 5 - Back Propagation Network

Purpose: To evaluate the performance of the back propagation neural network using a pixel representation of the target.

Method: The following steps were performed to analyze the back propagation network performance:

1. The back propagation network was created using the Instanet facility of the NeuralWare software package. The parameters used to create the network were:

   - Input 162 elements
   - Hidden layer 1, 4 elements
   - Output 10 elements.

   In addition to the basic network, the neural probe facility was used to create displays of the input and output layers. The neural probe is disabled during normal network operations but can be re-enabled using the appropriate menu options.

2. Five training files were created using the "nnimag" program. Each file consisted of 30 sets of 10 images (See B.1). The logs of the parameters entered to create the files are included in section D.5.1. The training files are named: BP1.NNI, BP2.NNI, BP3.NNI, BP4.NNI and BP5.NNI.

3. Four test files were created using the "nnimag" program. Each file consisted of 30 sets of 10 images (See B.1). The original images were modified by adding and/or modifying the peaks in the original images. The logs of the parameters entered to create the files are included in section D.5.2. The testing files and the number of added and/or modified peaks are as follows:

   - BPR1.NNI, 3 peaks
   - BPR2.NNI, 6 peaks
   - BPR3.NNI, 9 peaks
   - BPR4.NNI, 12 peaks.

4. The back propagation network created in step 1 was loaded and executed. Training and testing of the network were alternated once the network was able to correctly categorize the data with which it was being trained. The logs from the results analysis

program ("nnres") for each set of tests are included in section D.5.3.

5. The trained network has been saved as BP19500.NND.

Results: The results of the training and testing are summarized in the following table.

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	BPR1	BPR2	BPR3	BPR4
	BP1 BP2					
902	BP3* (Tol=.31)	60/300 20.0%				
	BP4 BP5					
1803	BP1* (Tol=.31)	180/300 60.0%				
	BP3 BP2					
2704	BP1* (Tol=.31)	210/300 70.0%				
	BP3 BP5					
3605	BP2* (Tol=.31)	210/300 70.0%				
	BP4 BP4					
4506	BP5* (Tol=.31)	270/300 90.0%				
	BP1 BP2					
5407	BP1* (Tol=.31)	210/300 70.0%				

A. EXPERIMENTS A.

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	BPR1	BPR2	BPR3	BPR4
	BP3 BP4					
6308	BP3* (Tol=.31)	270/300 90.0%				
	BP4 BP5					
7209	BP2* (Tol=.31)	300/300 100.0%				
7209	BP2* (Tol=.21)	270/300 90.0%				
	BP5 BP1					
8110	BP5* (Tol=.31)	300/300 100.0%	269/300 89.7%	231/300 77.0%	204/300 68.0%	181/300 60.3%
8110	BP5* (Tol=.21)	300/300 100.0%	257/300 85.7%	212/300 70.7%	185/300 61.7%	159/300 53.0%
	BP3 BP5					
9011	BP4* (Tol=.21)	300/300 100.0%				
9011	BP4* (Tol=.11)	300/300 100.0%				

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	BPR1	BPR2	BPR3	BPR4
	BP2 BP2 BP3 BP1					
10512	BP4* (Tol=.31)		268/300 89.3%	233/300 77.7%	207/300 69.0%	185/300 61.7%
10512	BP4* (Tol=.21)	300/300 100.0%	262/300 87.3%	218/300 72.7%	192/300 64.0%	167/300 55.7%
	BP5 BP2 BP3 BP3					
12013	BP1* (Tol=.31)		268/300 89.3%	235/300 78.3%	208/300 69.3%	186/300 62.0%
12013	BP1* (Tol=.21)	300/300 100.0%	265/300 88.3%	220/300 73.3%	199/300 66.3%	169/300 56.3%
	BP4 BP3 BP1 BP5 BP2 BP3 BP5 BP2 BP1					
15015	BP3* (Tol=.31)		269/300 89.7%	236/300 78.7%	212/300 70.7%	187/300 62.3%
15015	BP3* (Tol=.21)	300/300 100.0%	267/300 89.0%	220/300 73.3%	203/300 67.7%	170/300 56.7%

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	BPR1	BPR2	BPR3	BPR4
	BP5 BP2 BP1 BP4 BP4 BP5 BP4 BP1 BP5 BP4 BP3 BP3 BP2 BP1					
19518	BP2* (Tol=.31)		269/300 89.7%	238/300 79.3%	219/300 73.0%	187/300 62.3%
19518	BP2* (Tol=.21)	300/300 100.0%	267/300 89.0%	229/300 76.3%	203/300 67.7%	178/300 59.3%

* This training file was used to test the network during the testing phase.

Observations: It takes approximately 55 seconds to execute 300 learning presentations (i.e. LEARN ALL option for a training file) and approximately 45 seconds to execute 300 recalls (i.e. RECALL ALL option for a test file). These times are for a 16Mhz 80386 with a 80387 coprocessor running the optimized version of the NeuralWare software (i.e. n2f). The neural probes were disabled.

Conclusions: The back propagation network is able to solve the classification problem. This network should be included in further studies of this classification problem.

A.6 Experiment 6 - Adaline Network (Random Training 12 Peaks)

Purpose: To evaluate the performance of the Adaline neural network using a pixel representation of the target. Training was done using images which contained additional peaks and/or modified peaks.

Method: The following steps were performed to analyze the Adaline network performance:

1. The Adaline network was created using the Instanet facility of the NeuralWare software package. The parameters used to create the network were:

   - Input 648 elements
   - Output 10 elements.

   Note, in order to create this network, it is necessary to increase the default maximum number of processing elements which can be allocated by the NeuralWare software. This is done by specifying the following option when starting the software: -v700. This option must also be specified any time the Adaline network is executed.

2. Five training files were created using the "nnimag" program. Each file consisted of 30 sets of 10 images (See B.1). Each training file had 12 additional and/or modified peaks. The logs of the parameters entered to create the files are included in section D.6.1. The training files are named: ADR5.NNI, ADR6.NNI, ADR7.NNI, ADR8.NNI and ADR9.NNI.

3. The network was tested using files created for experiment 1. Each file consisted of 30 sets of 10 images (See B.1). The original images were modified by adding and/or modifying the peaks in the original images. The logs of the parameters entered to create the files are included in section D.1. The testing files and the number of added and/or modified peaks are as follows:

   - AD1.NNI, 0 peaks
   - ADR1.NNI, 3 peaks
   - ADR2.NNI, 6 peaks
   - ADR3.NNI, 9 peaks
   - ADR4.NNI, 12 peaks.

4. The Adaline network created in step 1 was loaded

and executed. The logs from the results analysis program ("nnres") for each set of tests are included in section D.6.2.

5. The trained network has been saved as ADN3300.NND.

Results: The results of the training and testing are summarized in the following table.

Total Number of Training Images	Training File(s)	Testing Files				
		AD1	ADR1	ADR2	ADR3	ADR4
302	ADR5	180/300 60.0%				
603	ADR6	300/300 100.0%				166/300 55.3%
904	ADR7	300/300 100.0%	291/300 97.0%			
1205	ADR8		298/300 99.3%			227/300 75.7%
1506	ADR9 ADR5					
2108	ADR7 ADR6					
2710	ADR5 ADR7					
3312	ADR9	300/300 100.0%	300/300 100.0%	296/300 98.7%	285/300 95.0%	272/300 90.7%

Observations: The network appears to converge in about five times as many trials as there are processing elements. This result agrees with that obtained by other experimenters.

It takes approximately 3.5 minutes to execute 300 learning presentations (i.e. LEARN ALL option for a training file) and approximately 2.3 minutes to execute 300 recalls (i.e. RECALL ALL option for a test file). These times are for a 16Mhz 80386 with a 80387 coprocessor running the optimized version of the NeuralWare software (i.e. n2f). The neural probes were disabled.

The Adaline network continues to learn even after it obtains the desired result. Thus, it is possible that further training could result in poorer performance.

Conclusions: The adaline network is able to solve the classification problem when the number of added and/or modified peaks was 12 or less pixels. The performance was much better when the network was trained on images with random peaks. Note, the number of pixels occupied by peaks in the original images is either 18 or 24 (i.e. 6 images have 3 peaks of 6 pixels each and 4 images have 4 peaks of 6 pixels each). This network should be included in further studies of this classification problem.

A.7 Experiment 7 - Adaline Network (Random Training 24 Peaks)

Purpose: To evaluate the performance of the Adaline neural network using a pixel representation of the target. Training was done using images which contained additional peaks and/or modified peaks.

Method: The following steps were performed to analyze the Adaline network performance:

1. The Adaline network was created using the Instanet facility of the NeuralWare software package. The parameters used to create the network were:

   - Input 648 elements
   - Output 10 elements.

   Note, in order to create this network, it is necessary to increase the default maximum number of processing elements which can be allocated by the NeuralWare software. This is done by specifying the following option when starting the software: -v700. This option must also be specified any time the Adaline network is executed.

2. Five training files were created using the "nnimag" program. Each file consisted of 30 sets of 10 images (See B.1). Each training file had 24 additional and/or modified peaks. The logs of the parameters entered to create the files are included in section D.7.1. The training files are named: ADR10.NNI, ADR11.NNI, ADR12.NNI, ADR13.NNI and ADR14.NNI.

3. The network was tested using files created for experiment 1. Each file consisted of 30 sets of 10 images (See B.1). The original images were modified by adding and/or modifying the peaks in the original images. The logs of the parameters entered to create the files are included in section D.1. The testing files and the number of added and/or modified peaks are as follows:

   - AD1.NNI, 0 peaks
   - ADR1.NNI, 3 peaks
   - ADR2.NNI, 6 peaks
   - ADR3.NNI, 9 peaks
   - ADR4.NNI, 12 peaks.

4. The Adaline network created in step 1 was loaded

and executed. The logs from the results analysis program ("nnres") for each set of tests are included in section D.7.2.

5. The trained network has been saved as ADNX3300.NND.

Results: The results of the training and testing are summarized in the following table.

Total Number of Training Images	Training File(s)	Testing Files				
		AD1	ADR1	ADR2	ADR3	ADR4
302	ADR10	150/300 50.0%				
603	ADR11	300/300 100.0%				173/300 57.7%
904	ADR12 ADR13					
1506	ADR14 ADR10					
2108	ADR12 ADR11					
2710	ADR10 ADR12					
3312	ADR14	300/300 100.0%	300/300 100.0%	299/300 99.7%	293/300 97.7%	289/300 96.3%

Observations: The network appears to converge in about five times as many trials as there are processing elements. This result agrees with that obtained by other experimenters.

It takes approximately 3.5 minutes to execute 300 learning presentations (i.e. LEARN ALL option for a training file) and approximately 2.3 minutes to execute 300 recalls (i.e. RECALL ALL option for a test file). These times are for a 16Mhz 80386 with a 80387 coprocessor running the optimized version of the NeuralWare software (i.e. n2f). The neural probes were disabled.

The Adaline network continues to learn even after it obtains the desired result. Thus, it is possible that further training could result in poorer performance.

Conclusions: The adaline network is able to solve the classification problem when the number of added and/or modified peaks was 12 or less pixels. The performance was much better when the network was trained on images with random peaks. Note, the number of pixels occupied by peaks in the original images is either 18 or 24 (i.e. 6 images have 3 peaks of 6 pixels each and 4 images have 4 peaks of 6 pixels each). This network should be included in further studies of this classification problem.

A.8 Experiment 8 - Back Propagation Network Random Training 24 Peaks

Purpose: To evaluate the performance of the back propagation neural network using a pixel representation of the target. The training was done using images with additional and/or modified peaks.

Method: The following steps were performed to analyze the back propagation network performance:

1. The back propagation network was created using the Instanet facility of the NeuralWare software package. The parameters used to create the network were:

   - Input 162 elements
   - Hidden layer 1, 4 elements
   - Output 10 elements.

2. Five training files were created using the "nnimag" program. Each file consisted of 30 sets of 10 images (See B.1). The logs of the parameters entered to create the files are included in section D.8.1. The training files are named: BPR5.NNI, BPR6.NNI, BPR7.NNI, BPR8.NNI and BPR9.NNI.

3. The network was tested using files created for experiment 5. Each file consisted of 30 sets of 10 images (See B.1). The original images were modified by adding and/or modifying the peaks in the original images. The logs of the parameters entered to create the files are included in section D.5. The testing files and the number of added and/or modified peaks are as follows:

   - BP1.NNI, 0 peaks
   - BPR1.NNI, 3 peaks
   - BPR2.NNI, 6 peaks
   - BPR3.NNI, 9 peaks
   - BPR4.NNI, 12 peaks.

4. The back propagation network created in step 1 was loaded and executed. The logs from the results analysis program ("nnres") for each set of tests are included in section D.8.2.

5. The trained network has been saved as BPN19500.NND.

Results: The results of the training and testing are summarized in the following table.

Total Number of Training Images	Training File(s)	Testing Files				
		BP1	**BPR1**	**BPR2**	**BPR3**	**BPR4**
0	**BPR5** **BPR6** **BPR7** **BPR8** **BPR9**					
1506	**BPR5** **BPR7** **BPR6** **BPR5** **BPR7**					
3007	**BPR9** **BPR6** **BPR8** **BPR8** **BPR9**					
4508	**BPR5** **BPR6** **BPR5** **BPR7** **BPR8**					
6009	**BPR7** **BPR8** **BPR9** **BPR6** **BPR9**					
7510	**BPR5** **BPR9** **BPR7** **BPR9** **BPR8**					

A. EXPERIMENTS A.

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	BPR1	BPR2	BPR3	BPR4
9011	BPR6 BPR6 BPR7 BPR5					
10212	BPR8 (Tol=.31)	180/300 60.0%	179/300 59.7%	179/300 59.7%	178/300 59.3%	179/300 59.7%
10512	BPR9 BPR6 BPR7 BPR7 BPR5					
12013	BPR8 BPR7 BPR5 BPR9 BPR6					
13514	BPR8 BPR9 BPR6 BPR5 BPR7					
15015	BPR9 BPR6 BPR5 BPR8 BPR8					
16516	BPR9 BPR8 BPR5 BPR9 BPR8					

Total Number of Training Images	Training File(s)	Testing Files				
		Training File	BPR1	BPR2	BPR3	BPR4
18017	BPR7 BPR7 BPR6 BPR5					
19218	BPR6 (Tol=.31)	180/300 60.0%	180/300 60.0%	178/300 59.3%	179/300 59.7%	179/300 59.7%

Observations: It takes approximately 55 seconds to execute 300 learning presentations (i.e. LEARN ALL option for a training file) and approximately 45 seconds to execute 300 recalls (i.e. RECALL ALL option for a test file). These times are for a 16Mhz 80386 with a 80387 coprocessor running the optimized version of the NeuralWare software (i.e. n2f). The neural probes were disabled.

Conclusions: The back propagation network does not perform well when trained using data with added and/or modified peaks.

A.9 Experiment 9 - Test Performance with Scaled, Translated, etc. Images

Purpose: To evaluate the performance of the Adaline, Hamming, recirculation and back propagation neural networks using a pixel representation of the target. A particular target was selected from the image file and various translations, scale operations etc. were performed to the target.

Method: The following steps were performed to analyze the network performance:

1. Test image number two was selected as a basis for the various operations (See B.1 for the image). Two new files were created. File name "image1" consisted of the following ten images:

   - image two was shifted one pixel left
   - image two was shifted two pixels left
   - image two was shifted three pixels left
   - image two was shifted one pixel right
   - image two was shifted two pixels right
   - image two was shifted three pixels right
   - image two was shifted down one pixel
   - image two was shifted down two pixels
   - image two was compressed by a factor of three in the horizontal dimension
   - image two was compressed by a factor of two in the vertical dimension.

   File name "image2" consisted of the following two images:

   - the new image was formed by reducing the 3 Horizontal by 2 Vertical pixel peaks in image two to a 1 Horizontal by 2 Vertical pixel peak. The middle horizontal element was used in the new image.

	1	2	3
1	X	M	X
2	X	M	X

	1	2	3
1	M		
2	M		

   - the new image was formed from image two by randomly selecting one of the 6 pixels in each peak.

2. Two test files were generated for each network to be tested. These files were generated by using files "image1" and "image2" as input to the "nnimag" program. Only one data set was used for testing. The data sets created using "image1" as input consisted of ten images and the data sets created using "image2" consisted of two images. The logs for the test files are contained in section D.9.1.

3. The networks which have been trained during previous experiments were loaded and executed. The networks used for testing are as follows:
   - Adaline network with random training ADNX3300.NND from experiment 7
   - Hamming network HAM10.NND from experiment 2
   - recirculation network REC7500.NND from experiment 4
   - back propagation network BP19500.NND from experiment 5

   The logs from the results analysis program ("nnres") for each set of tests are included in section D.9.1.

Results: The results of the training and testing are summarized in the following table.

Network Type	Testing Files		
	Image1	Image2	Total
Adaline	1/10 10.0%	0/2 10.0%	1/12 8.3%
Hamming	6/10 60.0%	1/2 50.0%	7/12 58.3%
Recirculation	0/10 0.0%	0/2 0.0%	0/12 0.0%
Back Propagation	2/10 20.0%	0/2 0.0%	2/12 16.7%

Observations: The recirculation network was close on two of the test images. It reproduced targets with low instead of medium peaks.

A. EXPERIMENTS A.

Conclusions: The neural networks fail miserably using this set of tests.

B. DATA CREATION B.

B.1 Image File

The image file consists of ten targets. Each target contains either 3 or 4 peaks. The peaks are designated as low, medium or high. The images are shown below. The following values were used when making up the image file:

(a) unlabelled squares were set to 0.0
(b) squares labelled L were set to 5.0
(c) squares labelled M were set to 10.0
(d) squares labelled H were set to 20.0.

Image One

	1				5					10					15					20					25		27
1																											
2																											
3	M	M	M				H	H	H										M	M	M				H	H	H
4	M	M	M				H	H	H										M	M	M				H	H	H
5																											
6																											

Image Two

	1				5					10					15					20					25		27
1							M	M	M										L	L	L						
2							M	M	M										L	L	L						
3	H	H	H																						H	H	H
4	H	H	H																						H	H	H
5																											
6																											

Image Three

	1				5					10					15					20					25		27
1																											
2																											
3	H	H	H																						H	H	H
4	H	H	H																						H	H	H
5							L	L	L										M	M	M						
6							L	L	L										M	M	M						

Image Four

	1				5					10					15					20					25		27
1							M	M	M																		
2							M	M	M																		
3	H	H	H																						M	M	M
4	H	H	H																						M	M	M
5																			L	L	L						
6																			L	L	L						

Image Five

	1				5					10					15					20					25		27
1																											
2																											
3	H	H	H				M	M	M																H	H	H
4	H	H	H				M	M	M																H	H	H
5																											
6																											

Image Six

	1				5					10					15					20					25		27
1							L	L	L																		
2							L	L	L																		
3	H	H	H																						M	M	M
4	H	H	H																						M	M	M
5																											
6																											

Image Seven

	1				5					10					15					20					25		27
1																											
2																											
3	H	H	H																						M	M	M
4	H	H	H																						M	M	M
5							L	L	L																		
6							L	L	L																		

Image Eight

	1				5					10					15					20					25		27
1																											
2																											
3	H	H	H										L	L	L										M	M	M
4	H	H	H										L	L	L										M	M	M
5																											
6																											

Image Nine

	1				5					10					15					20					25		27
1													L	L	L												
2													L	L	L												
3	M	M	M																						H	H	H
4	M	M	M																						H	H	H
5																											
6																											

Image Ten

	1				5					10					15					20					25		27
1																											
2																											
3	M	M	M																						H	H	H
4	M	M	M																						H	H	H
5													L	L	L												
6													L	L	L												

B.2 Image File Format

The image file was created using a standard editor. The file has the following format:

Record Number	Description
1	Header record containing number of images in file, number of rows per image, number of columns per row and number of classes
2	category of image one
3	row 1 of image 1
4	row 2 of image 1
5	row 3 of image 1
6	row 4 of image 1
7	row 5 of image 1
8	row 6 of image 1

where in this case

number of images = 10
number of rows per image = 6
number of columns per row = 27
number of classes = 10.

Records 2 through 8 are repeated once for each image in the file. The complete image file is shown below:

```
10 6 27 10
1
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

10.0 10.0 10.0  0.0  0.0  0.0 20.0 20.0 20.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
10.0 10.0 10.0  0.0  0.0  0.0 20.0 20.0 20.0

10.0 10.0 10.0  0.0  0.0  0.0 20.0 20.0 20.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
10.0 10.0 10.0  0.0  0.0  0.0 20.0 20.0 20.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

2
 0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 5.0  5.0  5.0  0.0  0.0  0.0  0.0  0.0  0.0

 0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 5.0  5.0  5.0  0.0  0.0  0.0  0.0  0.0  0.0

20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0 20.0 20.0 20.0

20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0 20.0 20.0 20.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

3
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
```

B. DATA CREATION B.

```
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 20.0 20.0 20.0

 20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 20.0 20.0 20.0

  0.0  0.0  0.0  0.0  0.0  0.0  5.0  5.0  5.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 10.0 10.0 10.0  0.0  0.0  0.0  0.0  0.0  0.0

  0.0  0.0  0.0  0.0  0.0  0.0  5.0  5.0  5.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 10.0 10.0 10.0  0.0  0.0  0.0  0.0  0.0  0.0

4
  0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

  0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0

 20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0

  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  5.0  5.0  5.0  0.0  0.0  0.0  0.0  0.0  0.0

  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  5.0  5.0  5.0  0.0  0.0  0.0  0.0  0.0  0.0

5
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 20.0 20.0 20.0  0.0  0.0  0.0 10.0 10.0 10.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 20.0 20.0 20.0

 20.0 20.0 20.0  0.0  0.0  0.0 10.0 10.0 10.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 20.0 20.0 20.0

  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
```

B. DATA CREATION B.

```
6
  0.0  0.0  0.0  0.0  0.0  0.0  5.0  5.0  5.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

  0.0  0.0  0.0  0.0  0.0  0.0  5.0  5.0  5.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0

 20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0

  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

7
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0

 20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0

  0.0  0.0  0.0  0.0  0.0  0.0  5.0  5.0  5.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

  0.0  0.0  0.0  0.0  0.0  0.0  5.0  5.0  5.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

8
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  5.0  5.0  5.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0

 20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
  0.0  0.0  0.0  5.0  5.0  5.0  0.0  0.0  0.0
  0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0

  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

9
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  5.0  5.0  5.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  5.0  5.0  5.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

10.0 10.0 10.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0 20.0 20.0 20.0

10.0 10.0 10.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0 20.0 20.0 20.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

10
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0

20.0 20.0 20.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0 10.0 10.0 10.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  5.0  5.0  5.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0

 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
 0.0  0.0  0.0  5.0  5.0  5.0  0.0  0.0  0.0
 0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0  0.0
```

B. DATA CREATION B.

B.2 Neural Network Input Files

Files must follow a specific format to be used as input to the NeuralWare software package. This format is described in reference [2], pages 277-279.

Before unique processing for networks which require either binary/bipolar or continuous inputs is performed, the following common processing is performed on the image:

(a) find maximum and minimum of the data

(b) optionally add peaks to the image data or modify the magnitude of existing peaks in the image data. See figures B.2.1 - B.2.6 for examples of images with added and/or modified peaks. The pixel to be modified is selected randomly.

If the pixel contains an existing peak (i.e. the pixel is not equal to the minimum value found in the image), then the magnitude of the peak is changed:

new pixel value = (old pixel value) * (random number) * (pixel scale factor)

where "random number" is a random number between 0.0 and 1.0 and "pixel scale factor" is a user entered scale factor.

If the pixel does not contain an existing peak (i.e. the pixel is equal to the minimum value found in the image), then the magnitude of the pixel is set to the maximum value found in the image and the processing described above is performed on the adjusted pixel value, i.e.

new pixel value = (maximum value) * (random number) * (pixel scale factor)

(c) optionally add random noise to the image. All pixels which are equal to the minimum value found in the image have noise added to them. The new value of the pixel is calculated as follows:

new pixel value = (noise level) * (random number)

where "random number" is a random number between 0.0 and 1.0 and "noise level " is a user entered scale factor.

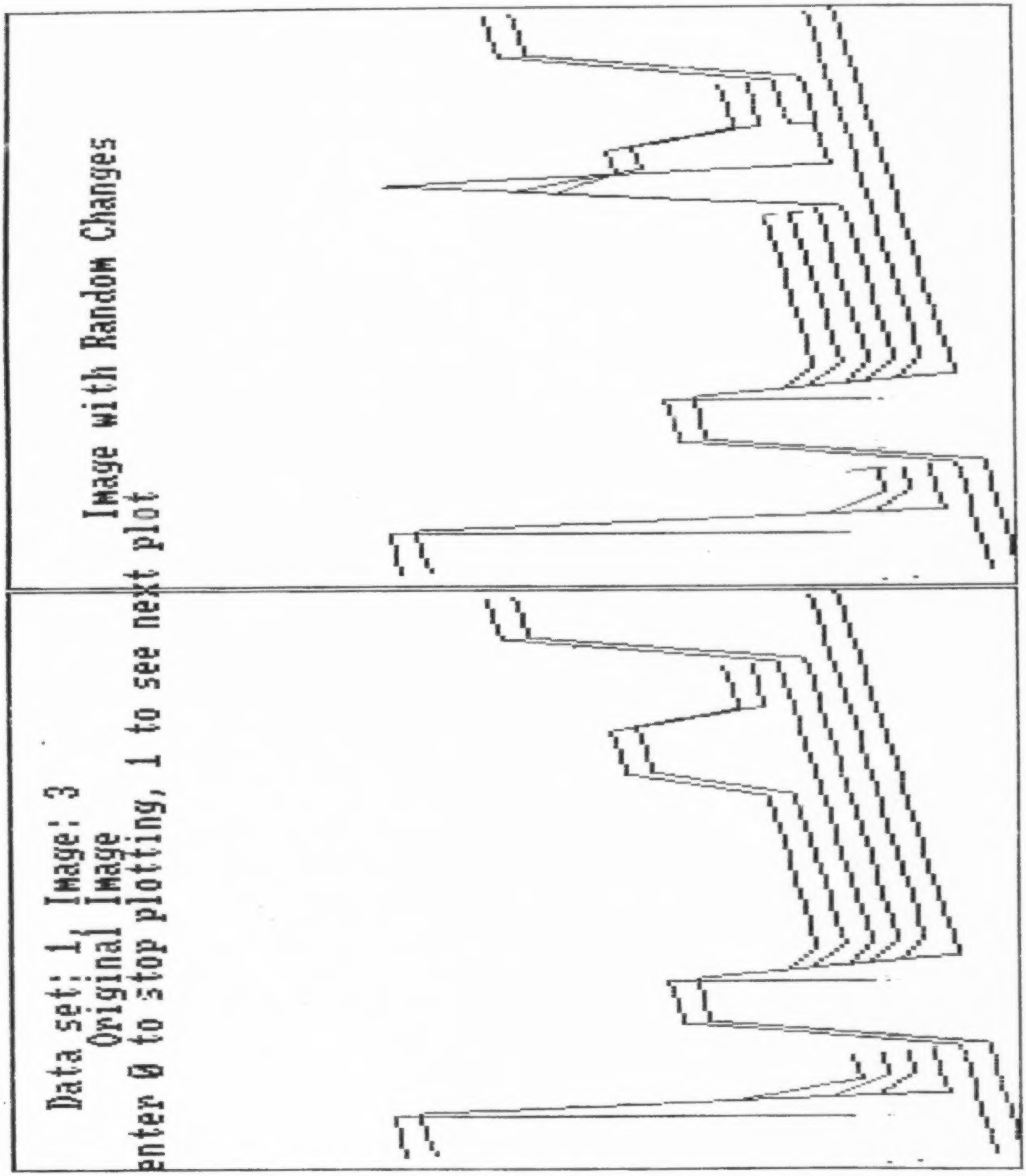
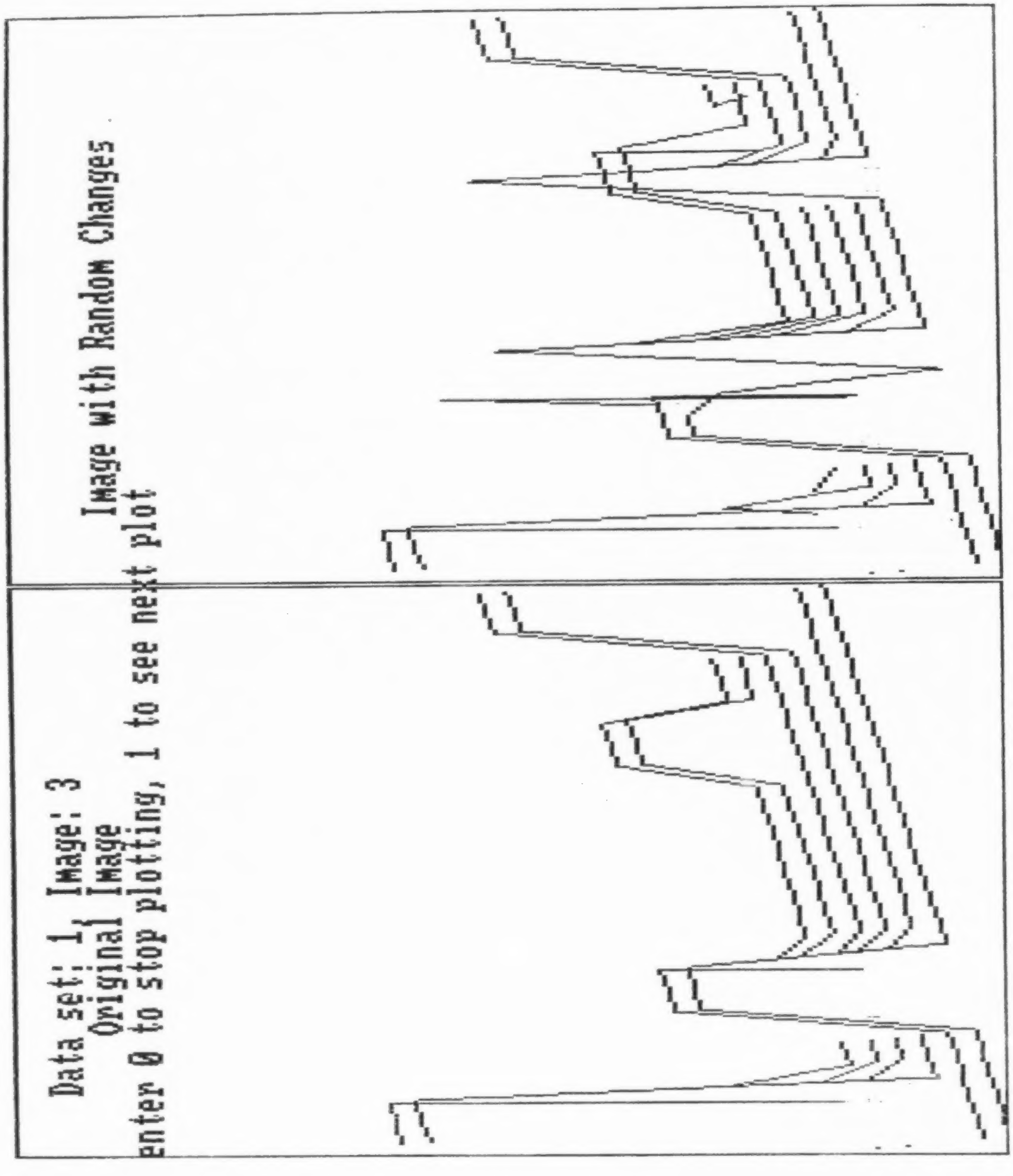


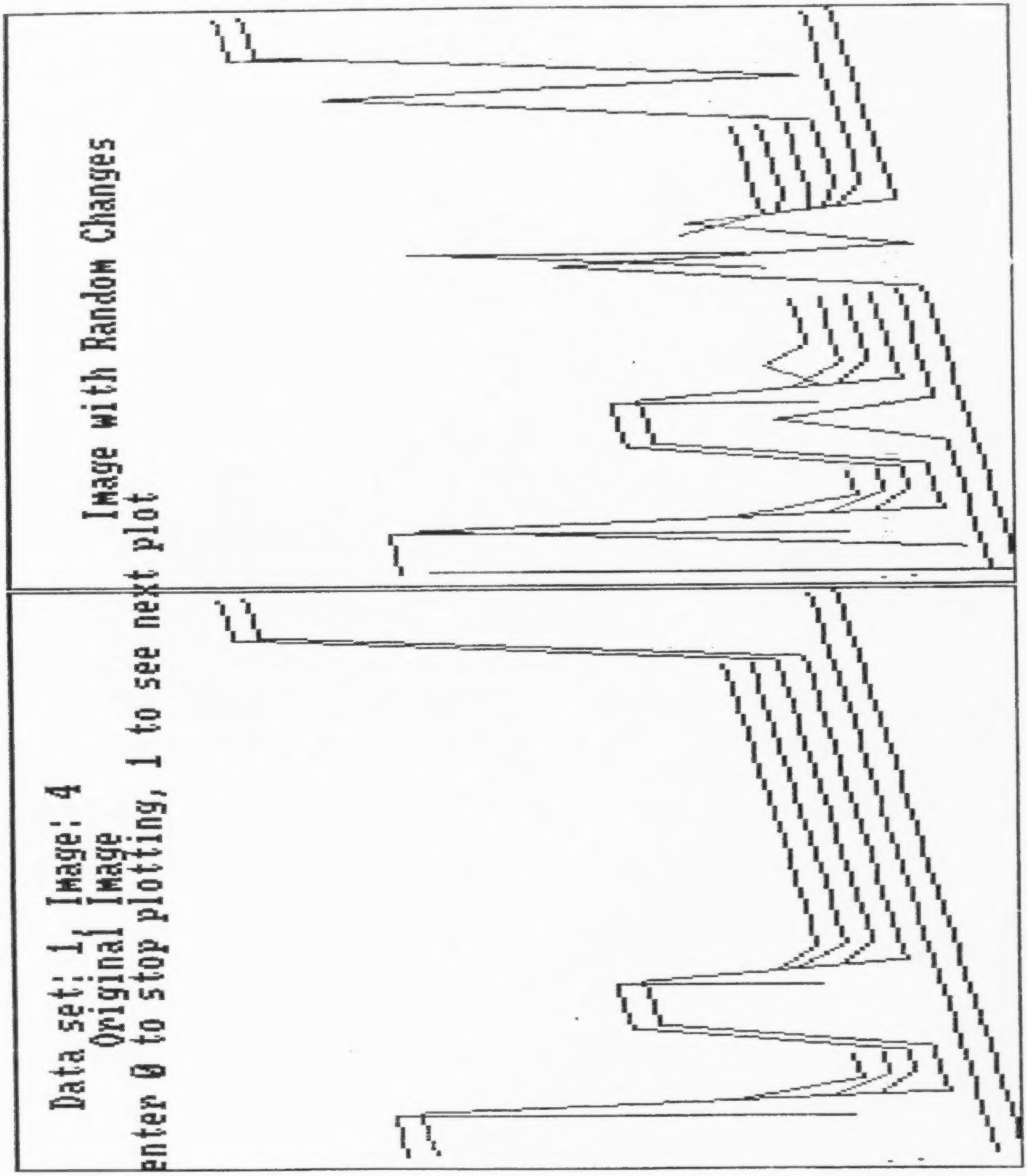
Figure B.2.1 - Example Image with 3 Added and/or Modified Peaks



Data set: 1, Image: 3
Original Image
enter 0 to stop plotting, 1 to see next plot

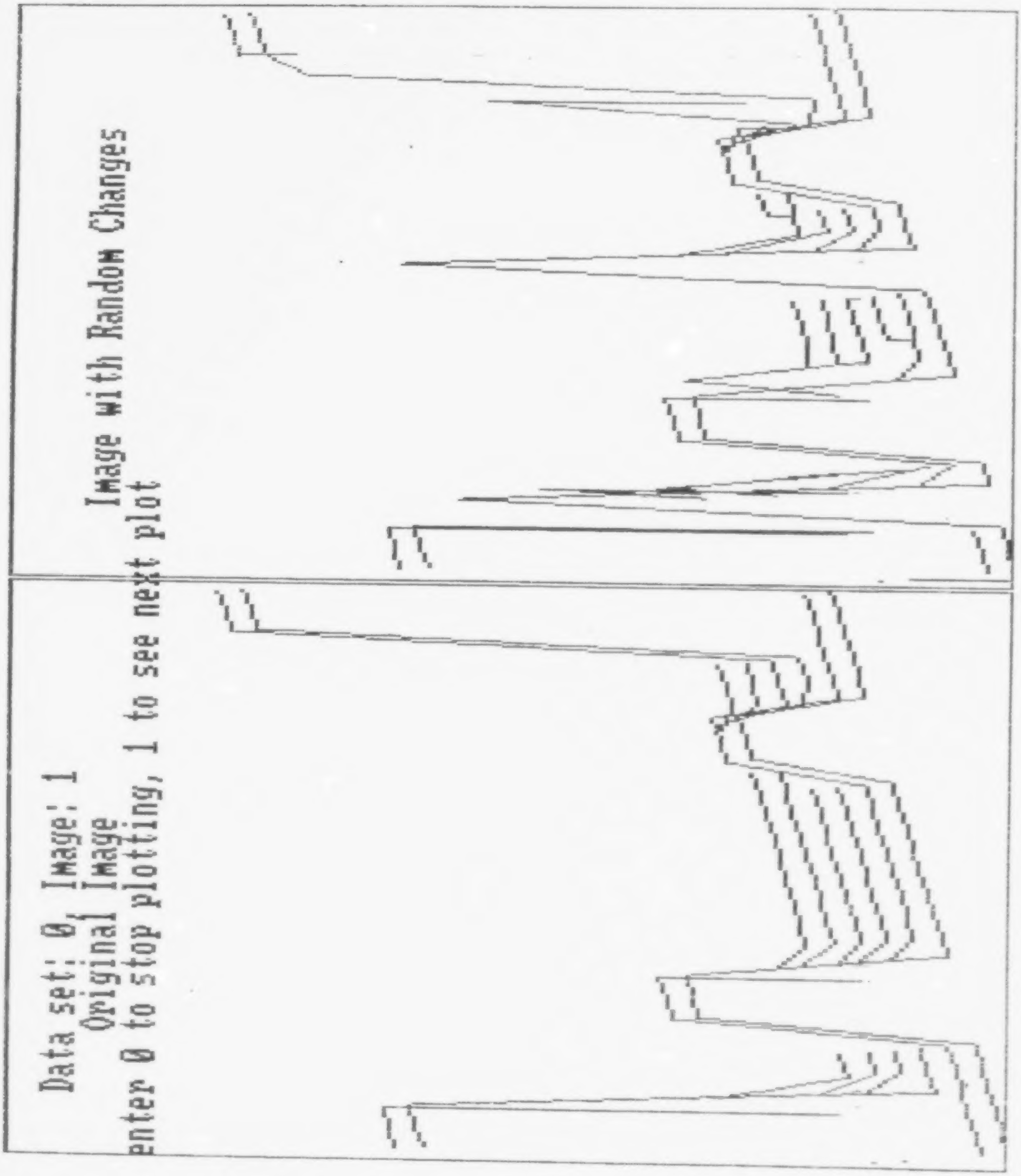
Image with Random Changes

Figure B.2.2 - Example Image with 6 Added and/or Modified Peaks



Data set: 1, Image: 4
Original Image
Image with Random Changes
enter 0 to stop plotting, 1 to see next plot

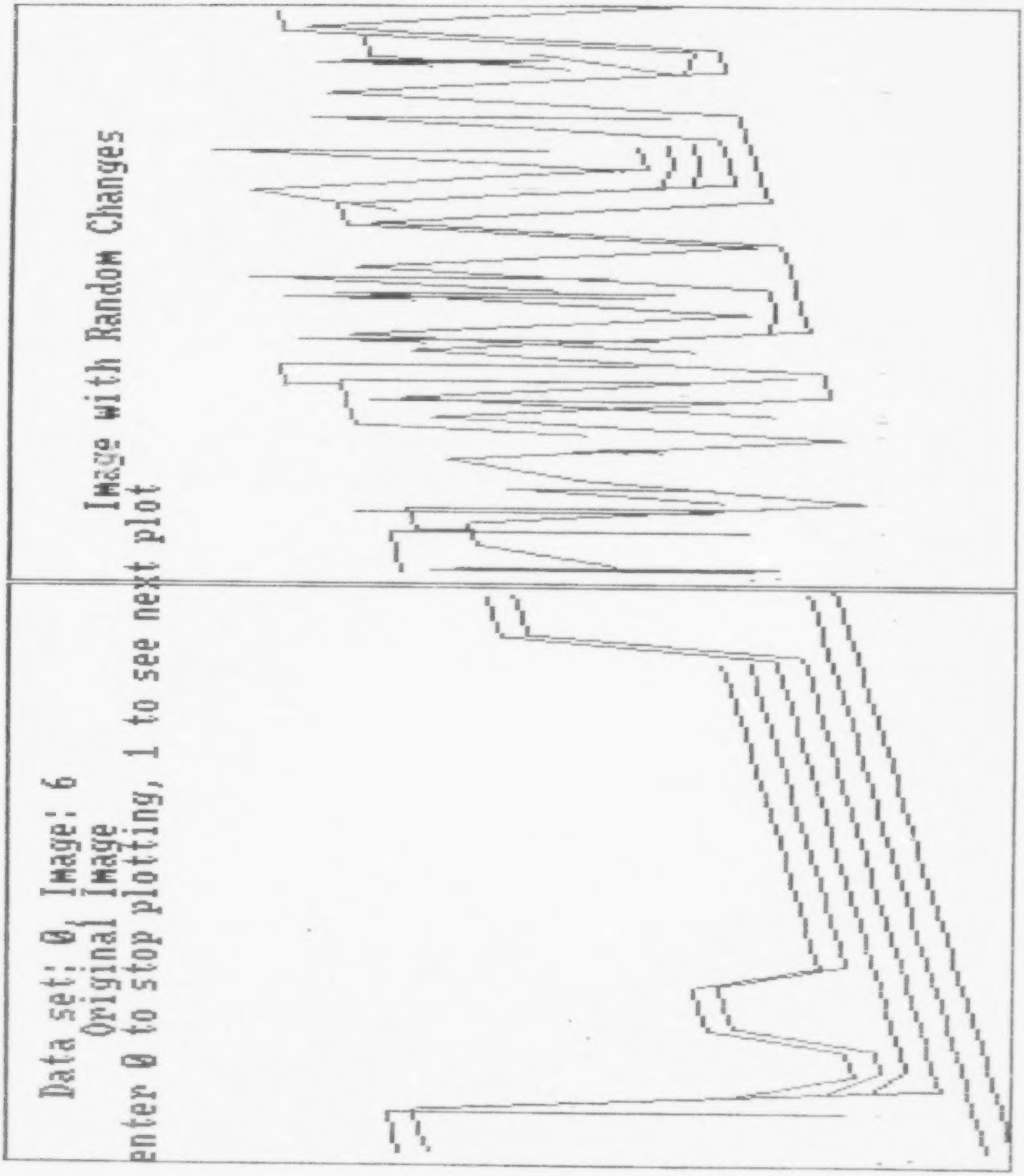
Figure B.2.3 - Example Image with 9 Added and/or Modified Peaks



```
Data set: 0, Image: 1
Original Image
enter 0 to stop plotting, 1 to see next plot
```

Image with Random Changes

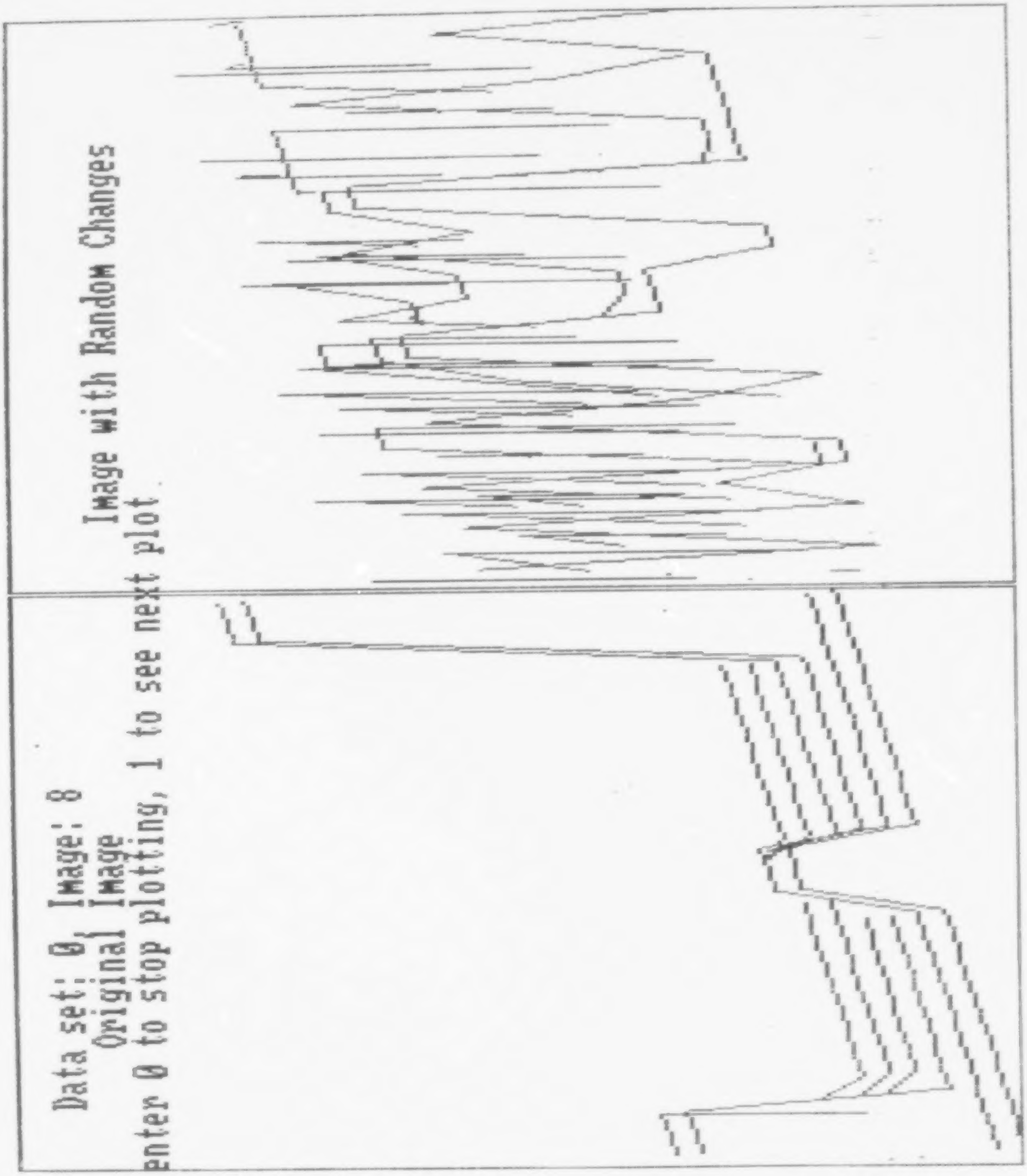
Figure B.2.4 - Example Image with 12 Added and/or Modified Peaks



Data set: 0, Image: 6
Original Image
enter 0 to stop plotting, 1 to see next plot

Image with Random Changes

Figure B.2.5 - Example Image with 48 Added and/or Modified Peaks



Data set: 0, Image: 8
Original Image
enter 0 to stop plotting, 1 to see next plot

Image with Random Changes

Figure B.2.6 - Example Image with 81 Added and/or Modified Peaks

B.2.1 Files for Binary/Bipolar Networks

Input to these networks must be coded using linearly separable codes (see reference [3], pages 376-377). The difference between the minimum pixel value and the maximum pixel value in the image file was divided into four regions. The actual numeric values of the ranges are output as part of the log files. Each pixel in the image is represented by four processing elements in the input layer of the neural network with only one of the four processing elements on and the other three elements off. In particular, the following coding is used:

If Pixel Value in Region	Processing Element Representation (0.0 = off, 1.0 = on)
1	1.0 0.0 0.0 0.0
2	0.0 1.0 0.0 0.0
3	0.0 0.0 1.0 0.0
4	0.0 0.0 0.0 1.0

B.2.2 Files for Continuous Networks

For these networks, the image data is scaled between 0.0 and 1.0:

scaled value = old pixel value / image data maximum

C. NETWORK LISTINGS C.

C.1 Adaline Network

```
Title: InstaNet (tm) Adaline Network version 1.00 20-Jun-88
                  Type: Hetero-Associative        Learn Data: Alpha (adaline)
          Display Mode: Hinton                   Recall Data: Alpha (adaline)
         Display Style: default                     User I/O: userio
      Control Strategy: adaline                 L/R Schedule: adaline
            4516 Learn                0 Recall                0 Layer
               0 Aux 1                0 Aux 2                 0 Aux 3
L/R Schedule: adaline
    Recall Step                1          0          0          0          0
      Input Clamp         0.0000     0.0000     0.0000     0.0000     0.0000
      Firing Density    100.0000     0.0000     0.0000     0.0000     0.0000
      Temperature         0.0000     0.0000     0.0000     0.0000     0.0000
      Gain                1.0000     0.0000     0.0000     0.0000     0.0000
      Modifier            1.0000     0.0000     0.0000     0.0000     0.0000
    Learn Step             10000          0          0          0          0
      Coefficient 1       0.2000     0.0000     0.0000     0.0000     0.0000
      Coefficient 2       0.0000     0.0000     0.0000     0.0000     0.0000
      Coefficient 3       0.0000     0.0000     0.0000     0.0000     0.0000
      Temperature         0.0000     0.0000     0.0000     0.0000     0.0000
Layer: 1
          PEs: 1                                     Sum: Sum
      Spacing: 5                                Transfer: Linear
        Shape: Square                             Output: Direct
        Scale: 1.00    Low Limit: -9999.00         Learn: --None--
       Offset: 0.00   High Limit: 9999.00   L/R Schedule: (Network)
     Winner 1: None                             Winner 2: None
Layer: In
          PEs: 648                                   Sum: Sum
      Spacing: 5                                Transfer: Linear
        Shape: Square                             Output: Direct
        Scale: 1.00    Low Limit: -9999.00         Learn: --None--
       Offset: 0.00   High Limit: 9999.00   L/R Schedule: (Network)
     Winner 1: None                             Winner 2: None
Layer: Adaline
          PEs: 10                                    Sum: Sum
      Spacing: 5                                Transfer: Signum
        Shape: Square                             Output: Direct
        Scale: 1.00    Low Limit: -9999.00         Learn: Adaline
       Offset: 0.00   High Limit: 9999.00   L/R Schedule: (Network)
     Winner 1: None                             Winner 2: None
Layer: Out
          PEs: 10                                    Sum: Sum
      Spacing: 5                                Transfer: Linear
        Shape: Square                             Output: Direct
        Scale: 1.00    Low Limit: -9999.00         Learn: --None--
       Offset: 0.00   High Limit: 9999.00   L/R Schedule: (Network)
     Winner 1: None                             Winner 2: None
```

C.2 Hamming Network

```
Title: InstaNet (tm) Hamming Network version 1.00 09-13-88
             Type: Hetero-Associative        Learn Data: Alpha (hamming)
     Display Mode: Hinton                   Recall Data: Alpha (hamming)
    Display Style: default                     User I/O: userio
 Control Strategy: hamming                 L/R Schedule: hamming
         11 Learn             1 Recall                  0 Layer
          0 Aux 1             0 Aux 2                   0 Aux 3
L/R Schedule: hamming
   Recall Step           50          0          0          0          0
     Input Clamp     0.0000     0.0000     0.0000     0.0000     0.0000
     Firing Density 100.0000    0.0000     0.0000     0.0000     0.0000
     Temperature     0.0000     0.0000     0.0000     0.0000     0.0000
     Gain            1.0000     0.0000     0.0000     0.0000     0.0000
     Modifier        1.0000     0.0000     0.0000     0.0000     0.0000
   Learn Step         99999          0          0          0          0
     Coefficient 1   0.5000     0.0000     0.0000     0.0000     0.0000
     Coefficient 2   0.0000     0.0000     0.0000     0.0000     0.0000
     Coefficient 3   0.0000     0.0000     0.0000     0.0000     0.0000
     Temperature     0.0000     0.0000     0.0000     0.0000     0.0000
Layer: 1
         PEs: 1                                         Sum: Sum
     Spacing: 5                                    Transfer: Linear
       Shape: Square                                 Output: Direct
       Scale: 1.00    Low Limit: -9999.00             Learn: --None--
      Offset: 0.00   High Limit: 9999.00       L/R Schedule: (Network)
    Winner 1: None                                 Winner 2: None
Layer: In
         PEs: 648                                       Sum: Sum
     Spacing: 5                                    Transfer: Signum
       Shape: Square                                 Output: Direct
       Scale: 1.00    Low Limit: -9999.00             Learn: --None--
      Offset: 0.00   High Limit: 9999.00       L/R Schedule: (Network)
    Winner 1: None                                 Winner 2: None
Layer: Category
         PEs: 10                                        Sum: Sum
     Spacing: 5                                    Transfer: Linear
       Shape: Square                                 Output: One-Highest
       Scale: 1.00    Low Limit: -9999.00             Learn: Widrow-Hoff
      Offset: 0.00   High Limit: 9999.00       L/R Schedule: (Network)
    Winner 1: None                                 Winner 2: None
Layer: Output
         PEs: 10                                        Sum: Sum
     Spacing: 5                                    Transfer: StepFunction
       Shape: Square                                 Output: Direct
       Scale: 1.00    Low Limit: -9999.00             Learn: --None--
      Offset: 0.00   High Limit: 9999.00       L/R Schedule: (Network)
    Winner 1: None                                 Winner 2: None
```

C. NETWORK LISTINGS C.

C.3 BAM Network

```
Title: InstaNet (tm) BAM Network version 1.00 20-Jun-88
                Type: Hetero-Associative        Learn Data: Alpha (bam)
        Display Mode: Hinton                   Recall Data: Alpha (bam)
       Display Style: default                     User I/O: userio
    Control Strategy: bam                     L/R Schedule: hopfield
           12 Learn                11 Recall                 0 Layer
            0 Aux 1                 0 Aux 2                  0 Aux 3
L/R Schedule: hopfield
   Recall Step              10          20           0           0           0
     Input Clamp        0.0000      0.0000      0.0000      0.0000      0.0000
     Firing Density    50.0000    100.0000      0.0000      0.0000      0.0000
     Temperature        0.0000      0.0000      0.0000      0.0000      0.0000
     Gain               1.0000      1.0000      0.0000      0.0000      0.0000
     Modifier           1.0000      1.0000      0.0000      0.0000      0.0000
   Learn Step            10000           0           0           0           0
     Coefficient 1      1.0000      0.0000      0.0000      0.0000      0.0000
     Coefficient 2      0.0000      0.0000      0.0000      0.0000      0.0000
     Coefficient 3      0.0000      0.0000      0.0000      0.0000      0.0000
     Temperature        0.0000      0.0000      0.0000      0.0000      0.0000
Layer: 1
        PEs: 1                                          Sum: Sum
    Spacing: 5                                     Transfer: Linear
      Shape: Square                                  Output: Direct
      Scale: 1.00     Low Limit: -9999.00             Learn: --None--
     Offset: 0.00    High Limit: 9999.00       L/R Schedule: (Network)
   Winner 1: None                                  Winner 2: None
Layer: In
        PEs: 648                                        Sum: Sum
    Spacing: 5                                     Transfer: Signum
      Shape: Square                                  Output: Direct
      Scale: 1.00     Low Limit: -9999.00             Learn: --None--
     Offset: 0.00    High Limit: 9999.00       L/R Schedule: (Network)
   Winner 1: None                                  Winner 2: None
Layer: BAM I
        PEs: 648                                        Sum: Sum
    Spacing: 5                                     Transfer: BAM
      Shape: Square                                  Output: Direct
      Scale: 1.00     Low Limit: -9999.00             Learn: BSB:Hebb
     Offset: 0.00    High Limit: 9999.00       L/R Schedule: (Network)
   Winner 1: None                                  Winner 2: None
Layer: BAM II
        PEs: 10                                         Sum: Sum
    Spacing: 5                                     Transfer: BAM
      Shape: Square                                  Output: Direct
      Scale: 1.00     Low Limit: -9999.00             Learn: BSB:Hebb
     Offset: 0.00    High Limit: 9999.00       L/R Schedule: (Network)
   Winner 1: None                                  Winner 2: None
Layer: Out
        PEs: 10                                         Sum: Sum
    Spacing: 5                                     Transfer: Linear
      Shape: Square                                  Output: Direct
      Scale: 1.00     Low Limit: -9999.00             Learn: --None--
     Offset: 0.00    High Limit: 9999.00       L/R Schedule: (Network)
   Winner 1: None                                  Winner 2: None
```

C.4 Recirculation Network

```
Title: InstaNet (tm) Recirculation Network version 1.00 26-08-88
             Type: Auto-Associative          Learn Data: Alpha (recirc)
     Display Mode: Hinton                   Recall Data: Alpha (recirc)
    Display Style: default                     User I/O: userio
 Control Strategy: recirc                  L/R Schedule: recirc
        7526 Learn                1 Recall              0 Layer
          10 Aux 1                0 Aux 2               0 Aux 3
L/R Schedule: recirc
   Recall Step            5           0           0           0           0
     Input Clamp     0.0000      0.0000      0.0000      0.0000      0.0000
     Firing Density 100.0000     0.0000      0.0000      0.0000      0.0000
     Temperature     0.0000      0.0000      0.0000      0.0000      0.0000
     Gain            1.0000      0.0000      0.0000      0.0000      0.0000
     Modifier        0.7500      0.0000      0.0000      0.0000      0.0000
   Learn Step         15000       30000           0           0           0
     Coefficient 1   0.1000      0.0500      0.0000      0.0000      0.0000
     Coefficient 2   0.0000      0.0000      0.0000      0.0000      0.0000
     Coefficient 3   0.0000      0.0000      0.0000      0.0000      0.0000
     Temperature     0.0000      0.0000      0.0000      0.0000      0.0000
Layer: 1
         PEs: 1                                      Sum: Sum
     Spacing: 5                                 Transfer: Linear
       Shape: Square                              Output: Direct
       Scale: 1.00    Low Limit: -9999.00          Learn: --None--
      Offset: 0.00   High Limit: 9999.00    L/R Schedule: (Network)
    Winner 1: None                              Winner 2: None
Layer: In
         PEs: 162                                    Sum: Sum
     Spacing: 5                                 Transfer: Linear
       Shape: Square                              Output: Direct
       Scale: 1.00    Low Limit: -9999.00          Learn: --None--
      Offset: 0.00   High Limit: 9999.00    L/R Schedule: (Network)
    Winner 1: None                              Winner 2: None
Layer: Visible
         PEs: 162                                    Sum: Sum
     Spacing: 5                                 Transfer: Sigmoid
       Shape: Square                              Output: Direct
       Scale: 1.00    Low Limit: -9999.00          Learn: Cum-Delta-Rule
      Offset: 0.00   High Limit: 9999.00    L/R Schedule: (Network)
    Winner 1: None                              Winner 2: None
Layer: Hidden
         PEs: 10                                     Sum: Sum
     Spacing: 5                                 Transfer: Sigmoid
       Shape: Square                              Output: Direct
       Scale: 1.00    Low Limit: -9999.00          Learn: Cum-Delta-Rule
      Offset: 0.00   High Limit: 9999.00    L/R Schedule: (Network)
    Winner 1: None                              Winner 2: None
Layer: Out
         PEs: 162                                    Sum: Sum
     Spacing: 5                                 Transfer: Linear
       Shape: Square                              Output: Direct
       Scale: 1.00    Low Limit: -9999.00          Learn: --None--
      Offset: 0.00   High Limit: 9999.00    L/R Schedule: (Network)
    Winner 1: None                              Winner 2: None
```

C.5 Back Propagation Network

```
Title: InstaNet (tm) Standard Back-Propagation Network version 1.00 20-Jun-88
                 Type: Hetero-Associative       Learn Data: Alpha (bkpstd)
         Display Mode: Hinton                  Recall Data: Alpha (bkpstd)
        Display Style: default                    User I/O: userio
     Control Strategy: backprop               L/R Schedule: backprop
          19518 Learn               0 Recall                 0 Layer
              0 Aux 1               0 Aux 2                  0 Aux 3
L/R Schedule: backprop
   Recall Step                 1          0          0          0          0
     Input Clamp          0.0000     0.0000     0.0000     0.0000     0.0000
     Firing Density     100.0000     0.0000     0.0000     0.0000     0.0000
     Temperature          0.0000     0.0000     0.0000     0.0000     0.0000
     Gain                 1.0000     0.0000     0.0000     0.0000     0.0000
     Modifier             1.0000     0.0000     0.0000     0.0000     0.0000
   Learn Step               5000          0          0          0          0
     Coefficient 1        0.9000     0.0000     0.0000     0.0000     0.0000
     Coefficient 2        0.6000     0.0000     0.0000     0.0000     0.0000
     Coefficient 3        0.0000     0.0000     0.0000     0.0000     0.0000
     Temperature          0.0000     0.0000     0.0000     0.0000     0.0000
Layer: 1
         PEs: 1                                            Sum: Sum
     Spacing: 5                                       Transfer: Linear
       Shape: Square                                    Output: Direct
       Scale: 1.00    Low Limit: -9999.00                Learn: --None--
      Offset: 0.00   High Limit: 9999.00          L/R Schedule: (Network)
    Winner 1: None                                    Winner 2: None
Layer: In
         PEs: 162                                          Sum: Sum
     Spacing: 5                                       Transfer: Linear
       Shape: Square                                    Output: Direct
       Scale: 1.00    Low Limit: -9999.00                Learn: --None--
      Offset: 0.00   High Limit: 9999.00          L/R Schedule: (Network)
    Winner 1: None                                    Winner 2: None
Layer: Hidden 1
         PEs: 4                                            Sum: Sum
     Spacing: 5                                       Transfer: Sigmoid
       Shape: Square                                    Output: Direct
       Scale: 1.00    Low Limit: -9999.00                Learn: Delta-Rule
      Offset: 0.00   High Limit: 9999.00          L/R Schedule: (Network)
    Winner 1: None                                    Winner 2: None
Layer: Out
         PEs: 10                                           Sum: Sum
     Spacing: 5                                       Transfer: Sigmoid
       Shape: Square                                    Output: Direct
       Scale: 1.00    Low Limit: -9999.00                Learn: Delta-Rule
      Offset: 0.00   High Limit: 9999.00          L/R Schedule: (Network)
    Winner 1: None                                    Winner 2: None
```

D. ADALINE LOGS D.

D.1 Adaline Network

D.1.1 Data Generation Logs (Training Files)

```
******************************************
*****        Data Generation         *****
*****   Mon Nov 27 15:07:56 1989     *****
******************************************

network type: 1

input file: image
   images:    10   rows:    6   columns:    27   classes:    10
output file: ad1.nni

binary: no                 bipolar: yes
continuous: no             training required: yes
randomize records: yes

random seed:     9910
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number        order of images in data set
      0               0   2   1   5   7   9   6   3   8   4
      1               6   5   0   7   2   8   3   9   1   4
      2               5   9   7   4   3   6   1   2   0   8
      3               9   1   3   7   0   8   2   5   4   6
      4               2   4   1   5   7   9   6   0   8   3
      5               4   8   0   9   3   2   7   6   5   1
      6               9   8   7   3   5   0   4   6   1   2
      7               8   7   1   0   3   5   9   6   4   2
      8               5   7   1   2   4   8   3   0   6   9
      9               1   0   9   2   6   7   5   8   3   4
     10               6   1   9   3   8   4   0   2   7   5
     11               9   5   4   8   1   0   3   6   7   2
     12               4   2   0   3   1   8   9   5   7   6
     13               7   0   5   9   3   6   2   1   8   4
     14               6   5   0   4   7   9   8   3   1   2
     15               5   0   1   4   8   7   9   6   2   3
     16               6   8   4   5   0   3   7   1   2   9
     17               7   3   5   8   6   9   4   2   0   1
     18               3   8   4   5   6   1   2   9   0   7
     19               6   1   4   5   8   9   0   7   2   3
     20               3   4   2   5   8   6   7   0   9   1
     21               6   0   1   4   2   5   7   9   8   3
     22               2   9   7   4   1   8   3   0   5   6
     23               6   9   5   8   2   7   0   4   3   1
     24               1   3   8   4   7   0   9   6   2   5
     25               4   1   7   2   5   6   0   8   3   9
     26               2   5   4   9   8   3   1   6   7   0
     27               1   0   8   9   3   6   4   2   5   7
     28               3   9   7   6   0   8   2   4   1   5
     29               9   8   7   4   0   3   5   1   6   2
```

```
****************************************
*****        Data Generation       *****
*****   Mon Nov 27 15:17:06 1989   *****
****************************************

network type: 1

input file: image
   images:    10   rows:     6  columns:    27   classes:    10
output file: ad2.nni

binary: no                bipolar: yes
continuous: no            training required: yes
randomize records: yes

random seed:      1576
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number       order of images in data set
      0               4   7   2   9   8   3   6   0   1   5
      1               1   9   2   3   0   5   4   7   8   6
      2               2   0   3   4   9   1   5   8   7   6
      3               8   0   3   2   4   9   7   6   5   1
      4               7   5   4   8   1   3   6   0   2   9
      5               8   9   2   7   5   1   0   3   4   6
      6               8   3   4   6   9   1   5   2   7   0
      7               1   2   5   6   0   8   3   9   4   7
      8               9   3   4   8   5   2   1   0   7   6
      9               3   7   9   1   0   8   5   6   4   2
     10               8   6   5   1   7   2   0   9   3   4
     11               4   9   6   8   0   2   3   7   1   5
     12               4   8   5   6   7   2   0   3   9   1
     13               0   4   7   8   9   6   1   3   5   2
     14               9   2   6   4   0   3   8   7   5   1
     15               2   4   3   5   6   8   7   0   9   1
     16               5   1   7   3   4   8   9   6   0   2
     17               5   7   9   0   3   1   2   6   4   8
     18               8   0   3   4   7   9   6   5   1   2
     19               6   8   0   7   3   4   5   2   9   1
     20               5   4   8   9   3   1   7   2   6   0
     21               9   3   2   6   1   7   5   0   4   8
     22               9   2   4   8   1   6   3   5   0   7
     23               2   1   8   9   0   4   7   6   3   5
     24               9   4   8   3   6   7   1   0   5   2
     25               3   8   2   1   5   7   6   4   0   9
     26               9   6   3   0   2   4   8   5   7   1
     27               8   4   2   6   3   1   5   0   9   7
     28               7   5   3   6   0   4   8   1   9   2
     29               8   6   4   9   7   1   0   5   2   3
```

```
****************************************
*****        Data Generation       *****
*****   Mon Nov 27 15:25:54 1989   *****
****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: ad3.nni

binary: no                 bipolar: yes
continuous: no             training required: yes
randomize records: yes

random seed:     4589
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number       order of images in data set
      0            4   7   6   8   0   3   2   1   9   5
      1            4   2   9   5   0   8   6   7   1   3
      2            7   0   4   1   8   3   9   5   2   6
      3            4   7   1   0   5   3   6   9   8   2
      4            8   5   1   3   7   0   2   4   9   6
      5            0   3   5   9   6   8   4   1   2   7
      6            2   6   8   3   1   5   0   9   7   4
      7            2   3   4   6   7   5   9   8   1   0
      8            5   3   0   7   2   4   1   6   9   8
      9            9   2   6   1   0   3   7   5   4   8
     10            6   5   4   0   3   1   7   2   9   8
     11            2   4   5   6   3   1   9   7   0   8
     12            9   1   8   0   7   5   2   3   6   4
     13            4   9   6   2   0   1   7   8   3   5
     14            2   0   4   7   9   1   6   8   5   3
     15            9   7   3   8   6   1   0   5   4   2
     16            7   4   5   3   8   1   0   9   2   6
     17            6   8   4   0   2   7   3   5   1   9
     18            7   0   5   6   1   3   4   9   2   8
     19            9   8   1   5   2   7   0   4   3   6
     20            8   3   5   7   2   0   6   9   1   4
     21            3   7   2   6   5   8   1   9   0   4
     22            3   7   5   0   1   6   2   9   8   4
     23            2   3   9   5   7   8   6   4   1   0
     24            3   2   1   8   6   7   4   9   5   0
     25            1   8   9   5   2   3   6   0   4   7
     26            3   4   6   0   8   2   1   5   7   9
     27            4   7   5   3   6   1   2   8   9   0
     28            6   4   2   0   9   7   1   3   8   5
     29            2   6   1   4   5   9   7   3   8   0
```

```
*****************************************
*****        Data Generation        *****
*****  Mon Nov 27 15:32:58 1989     *****
*****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: ad4.nni

binary: no                 bipolar: yes
continuous: no             training required: yes
randomize records: yes

random seed:     6317
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number       order of images in data set
     0             7   8   6   2   3   5   1   0   4   9
     1             5   7   3   0   6   4   8   9   2   1
     2             8   4   3   0   6   1   7   9   2   5
     3             1   9   8   0   3   5   4   2   7   6
     4             4   2   1   0   9   5   6   7   8   3
     5             2   5   6   8   0   7   9   1   4   3
     6             3   0   6   8   4   9   5   1   2   7
     7             0   7   1   8   4   2   6   9   3   5
     8             8   2   6   7   1   9   5   4   0   3
     9             6   1   5   9   0   2   8   4   3   7
    10             3   1   4   2   5   8   9   7   6   0
    11             1   8   7   6   2   5   0   9   4   3
    12             8   9   0   7   5   2   4   3   1   6
    13             1   9   7   6   5   4   3   2   0   8
    14             1   4   8   9   0   2   3   6   7   5
    15             8   6   9   1   0   7   3   2   4   5
    16             4   7   6   8   5   1   3   0   2   9
    17             0   2   7   3   8   9   6   4   5   1
    18             1   5   3   6   2   7   8   9   4   0
    19             6   4   5   3   8   7   0   2   9   1
    20             6   9   8   3   7   5   4   1   0   2
    21             4   3   8   5   1   2   6   0   9   7
    22             3   7   8   9   1   4   2   6   5   0
    23             4   3   5   7   2   0   9   1   8   6
    24             1   3   6   7   9   2   8   4   0   5
    25             9   3   4   8   2   5   1   0   7   6
    26             3   2   8   7   1   9   5   0   4   6
    27             0   3   9   7   1   5   6   4   8   2
    28             1   3   4   5   9   7   6   8   0   2
    29             0   6   4   3   1   9   8   2   7   5
```

D. ADALINE LOGS D.

```
*****************************************
*****         Data Generation       *****
*****   Mon Nov 27 15:40:20 1989    *****
*****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: ad5.nni

binary: no              bipolar: yes
continuous: no          training required: yes
randomize records: yes

random seed:     7371
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number       order of images in data set
     0              0   5   7   8   2   1   6   3   4   9
     1              3   2   9   7   8   0   4   5   1   6
     2              7   0   9   2   3   1   4   6   5   8
     3              9   8   2   7   6   1   0   5   3   4
     4              3   0   8   4   9   6   5   1   2   7
     5              6   1   7   2   3   4   8   9   5   0
     6              8   9   3   7   1   6   0   5   4   2
     7              5   4   7   0   1   3   9   8   2   6
     8              3   4   8   5   9   1   7   6   0   2
     9              1   5   3   8   0   6   9   7   4   2
    10              7   4   2   5   8   0   9   6   3   1
    11              2   9   6   0   3   4   1   5   8   7
    12              0   9   1   3   6   7   5   2   4   8
    13              7   2   3   5   9   0   6   8   1   4
    14              4   6   1   7   8   3   0   5   9   2
    15              6   3   7   2   0   1   9   5   8   4
    16              8   0   2   9   6   1   7   3   5   4
    17              4   9   5   8   3   0   2   6   1   7
    18              3   4   0   9   1   7   8   5   6   2
    19              2   3   4   9   1   8   7   0   6   5
    20              5   2   1   6   3   7   9   4   8   0
    21              6   2   5   7   8   1   0   4   9   3
    22              1   6   5   4   7   8   3   2   9   0
    23              7   5   2   3   8   0   4   1   9   6
    24              2   3   0   7   5   6   1   4   9   8
    25              1   3   8   6   5   2   4   9   0   7
    26              5   4   7   6   8   2   1   9   3   0
    27              8   2   0   4   7   1   9   3   5   6
    28              0   3   9   4   5   6   1   8   2   7
    29              5   8   9   4   2   0   6   3   7   1
```

D.1.2 Data Generation Logs (Testing Files)

```
****************************************
*****         Data Generation      *****
*****   Mon Nov 27 15:47:52 1989   *****
****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: adr1.nni

binary: no                  bipolar: yes
continuous: no              training required: yes
randomize records: yes

random seed:      8767
number of pixels to randomize in peaks: 3, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number         order of images in data set
      0            1   9   8   4   7   2   3   6   5   0
      1            8   6   1   3   5   4   0   7   9   2
      2            9   7   1   6   5   0   2   3   8   4
      3            9   3   7   4   6   2   8   5   1   0
      4            6   5   2   0   3   4   7   8   9   1
      5            3   7   9   0   1   2   4   5   6   8
      6            2   0   6   9   3   5   1   7   4   8
      7            5   4   0   1   6   8   3   7   2   9
      8            1   5   0   8   7   4   2   3   6   9
      9            0   4   9   8   5   2   3   7   1   6
     10            3   6   1   5   7   4   2   8   0   9
     11            7   6   8   0   9   1   2   5   4   3
     12            9   0   2   1   5   8   6   7   3   4
     13            2   0   1   4   3   6   5   9   8   7
     14            8   6   5   7   9   1   0   2   3   4
     15            0   2   8   4   1   7   9   6   5   3
     16            6   3   5   1   8   9   7   4   0   2
     17            4   7   5   9   8   1   2   6   0   3
     18            6   9   0   5   4   1   3   8   2   7
     19            5   3   6   2   9   8   0   4   7   1
     20            9   1   5   0   6   4   2   8   3   7
     21            7   0   6   4   5   1   8   3   9   2
     22            2   1   7   5   0   6   3   9   8   4
     23            2   7   0   8   6   5   9   1   4   3
     24            5   7   3   8   9   6   1   2   0   4
     25            6   2   1   8   5   9   0   7   4   3
     26            7   1   9   2   3   0   5   6   8   4
     27            8   0   3   5   1   4   7   9   6   2
     28            0   4   6   8   7   1   5   3   2   9
     29            5   9   4   7   2   3   6   0   1   8
```

D. ADALINE LOGS D.

```
*****************************************
*****        Data Generation       *****
*****   Mon Nov 27 15:55:30 1989   *****
*****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: adr2.nni

binary: no               bipolar: yes
continuous: no           training required: yes
randomize records: yes

random seed:     1737
number of pixels to randomize in peaks: 6, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number      order of images in data set
     0             6   1   4   8   3   5   7   0   2   9
     1             2   1   9   8   3   4   0   5   7   6
     2             0   9   6   7   5   2   8   4   1   3
     3             6   3   9   4   2   0   8   1   7   5
     4             3   5   9   2   0   4   8   6   1   7
     5             2   0   9   4   8   6   1   7   3   5
     6             4   8   3   5   9   2   7   1   6   0
     7             0   7   1   5   2   3   6   9   4   8
     8             0   7   4   6   5   8   2   3   1   9
     9             7   6   4   5   9   1   2   0   8   3
    10             0   8   6   1   7   4   9   5   3   2
    11             9   0   2   8   6   5   3   4   7   1
    12             4   8   7   9   2   5   3   0   1   6
    13             7   4   1   0   5   3   8   2   9   6
    14             1   4   2   0   9   3   5   8   7   6
    15             1   2   9   3   8   0   6   7   4   5
    16             4   6   5   8   9   0   7   3   1   2
    17             6   2   4   1   3   5   0   9   8   7
    18             6   4   0   8   7   5   9   1   2   3
    19             4   6   9   0   5   1   8   3   7   2
    20             4   3   8   5   2   0   6   7   1   9
    21             3   4   2   9   0   5   8   7   1   6
    22             3   0   7   4   5   8   2   1   9   6
    23             1   9   8   5   6   2   0   3   7   4
    24             2   7   8   1   9   0   4   3   5   6
    25             2   8   4   0   3   7   5   1   6   9
    26             4   0   3   9   7   6   5   8   1   2
    27             3   4   0   1   8   5   6   9   2   7
    28             6   7   3   0   5   2   8   9   1   4
    29             5   8   1   9   6   7   0   4   2   3
```

D. ADALINE LOGS D.

```
***************************************
*****        Data Generation      *****
*****   Mon Nov 27 16:02:54 1989  *****
***************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: adr3.nni

binary: no                bipolar: yes
continuous: no            training required: yes
randomize records: yes

random seed:      2711
number of pixels to randomize in peaks: 9, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number      order of images in data set
     0               7   0   2   5   6   4   3   8   9   1
     1               1   7   6   4   9   3   2   8   5   0
     2               4   5   9   0   8   3   1   2   6   7
     3               7   4   8   6   1   9   3   2   5   0
     4               6   2   0   8   3   1   9   4   5   7
     5               6   8   5   2   1   0   4   7   3   9
     6               4   7   9   1   2   3   8   5   6   0
     7               8   2   3   5   7   6   4   1   9   0
     8               6   2   9   3   1   5   0   7   8   4
     9               5   4   9   3   2   6   8   1   7   0
    10               8   7   4   2   3   5   0   1   6   9
    11               0   9   2   7   1   8   6   5   3   4
    12               9   2   4   6   1   3   8   7   5   0
    13               5   9   3   1   0   8   7   2   4   6
    14               1   4   2   5   3   9   8   0   7   6
    15               8   3   5   9   7   4   2   1   6   0
    16               0   4   6   9   5   2   7   3   8   1
    17               8   2   5   1   4   7   3   9   6   0
    18               8   0   9   3   7   1   4   5   2   6
    19               1   0   5   6   8   4   9   2   7   3
    20               4   8   5   6   2   3   0   1   9   7
    21               2   0   8   6   4   9   5   3   1   7
    22               7   3   9   5   6   0   8   1   2   4
    23               0   8   9   5   2   7   3   6   1   4
    24               1   4   5   2   7   0   8   6   3   9
    25               2   4   8   9   7   3   0   6   5   1
    26               1   8   3   7   0   9   4   6   5   2
    27               9   1   5   6   7   0   3   4   8   2
    28               4   1   3   6   0   5   2   8   7   9
    29               2   3   0   9   7   6   4   1   5   8
```

D. ADALINE LOGS D.

```
****************************************
*****       Data Generation       *****
*****  Mon Nov 27 16:10:12 1989   *****
****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: adr4.nni

binary: no                bipolar: yes
continuous: no            training required: yes
randomize records: yes

random seed:      5929
number of pixels to randomize in peaks: 12, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number        order of images in data set
     0                7   1   5   4   8   6   9   2   3   0
     1                1   6   0   5   3   8   9   4   2   7
     2                9   3   5   1   0   4   7   6   2   8
     3                5   1   3   2   8   9   7   6   0   4
     4                3   5   1   0   4   2   6   9   8   7
     5                3   8   7   4   2   9   5   1   0   6
     6                9   7   5   0   2   3   8   6   4   1
     7                1   5   3   8   4   0   7   9   6   2
     8                5   4   6   8   7   2   3   1   9   0
     9                8   0   4   1   7   3   2   6   9   5
    10                7   8   2   6   4   5   1   9   0   3
    11                9   7   4   1   0   5   2   8   3   6
    12                5   9   2   7   1   3   0   6   8   4
    13                7   9   8   6   0   2   1   5   4   3
    14                0   9   5   1   8   7   3   2   6   4
    15                5   8   3   2   7   0   1   9   4   6
    16                6   5   1   2   0   4   7   3   8   9
    17                7   4   9   0   5   1   3   6   2   8
    18                3   6   9   8   1   2   7   0   4   5
    19                2   7   4   1   0   9   5   3   8   6
    20                3   7   2   6   8   5   4   0   1   9
    21                1   2   3   0   5   7   6   4   9   8
    22                9   0   2   8   7   3   6   1   4   5
    23                2   5   3   4   6   1   0   9   8   7
    24                5   8   4   1   9   6   3   2   7   0
    25                3   4   8   9   2   5   6   1   0   7
    26                8   5   9   4   1   3   6   7   0   2
    27                3   2   5   4   0   9   1   6   7   8
    28                2   7   9   8   4   1   3   5   6   0
    29                8   0   6   2   9   1   5   3   4   7
```

D.1.3 Test Results Logs

(a) Results after 302 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Mon Nov 27 16:30:36 1989   *****
****************************************

network type: 1

expected values file: ad1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

       1             5, 10, 14, 20, 23, 24, 34, 39, 42, 45, 51
       1            57, 63, 67, 72, 79, 82, 85, 96,100,106,109
       1           113,119,121,129,131,140,144,145,154,156,163
       1           167,171,177,183,190,193,198,202,207,214,217
       1           223,224,236,238,244,245,251,253,263,269,277
       1           280,283,288,293,294

number correct: 240, total input: 300, per cent correct: 80.0
```

(b) Results after 603 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Mon Nov 27 16:40:08 1989   *****
****************************************

network type: 1

expected values file: ad2.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****        Data Comparison       *****
*****   Mon Nov 27 16:47:50 1989   *****
****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

       1             4, 18, 31, 33, 41, 47, 57, 63, 66, 75, 82
       1           115,125,144,157,158,171,182,187,193,198,213
       1           224,230,242,246,268,271,290

number correct: 271, total input: 300, per cent correct: 90.3
```

D. ADALINE LOGS D.

```
****************************************
*****        Data Comparison       *****
*****   Mon Nov 27 16:52:58 1989   *****
****************************************

network type: 1

expected values file: adr2.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

       1             1,  6, 14, 16, 18, 19, 24, 25, 28,
       2            33
       1            34, 39, 43, 48, 50, 54, 60, 64, 67, 69, 70
       1            71, 73, 76, 79, 83, 84, 85, 88, 91, 93, 94
       1           103,107
       2           108
       1           118,121,130,133,139,141,148,149,160,161,169
       1           170
       2           172
       1           173,176,179,181,182,186
       3           201
       1           203
       2           207
       1           208,212,213,215,216,224,238
       2           242
       1           249,259,260,261,266,271,277
       2           281
       1           289,290,291,292,298

number correct: 222, total input: 300, per cent correct: 74.0

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 13:46:56 1989   *****
****************************************

network type: 1

expected values file: adr3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

       1             2,  4,  5,  6,  8, 11, 14, 16, 21, 23
       2            26
       1            28, 30
       3            33
       1            38, 39, 40, 42
       2            44
       1            45, 48, 51, 52, 53, 54, 57, 59
       2            60
       3            61
       2            62
       1            68, 72, 76
       2            77, 84, 88
       1            89, 91
       2            93, 94
       1            95
       2           102
       1           103,104,107,113,117,118
```

```
      2           122
      1           123,125
      2           129
      1           131,132,137
      3           138
      1           139,140,143
      2           145
      1           146,151
      3           153
      1           155
      2           157, 158
      1           162,166,169,172,173,175,176,177
      2           179
      1           185,186,187
      3           188
      1           190,197,200,202,204,206,211,217,220,221,223
      1           225,230,231,232,236,238,240,241,246,248,255
      1           258,260,261,262,263,265
      2           268
      1           271,281,282,283,289,290,291
      3           295
      1           296,297,298,299

number correct: 180, total input: 300, per cent correct: 60.0

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 13:51:12 1989   *****
****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1             2
      2             4
      1            12, 17, 19, 20, 23, 29
      3            30
      1            31, 33, 34
      2            35
      1            36, 37, 38, 40, 43, 44
      2            45
      1            46, 48, 49, 51, 53, 54,
      2            57
      1            61, 62
      2            63
      1            68, 69, 70
      2            71
      1            72, 74, 75, 77, 78
      3            79
      1            80
      3            82
      2            86, 87
      1            88, 90
      2            95
      1            98,101,102
      2           103
      1           105
      3           106
      1           110,120,122,127
      2           128
      1           131
      2          132
      1          133,134,143,145,146,147,148,150
      2          151,153
      1          156,157,158,164,165
      2          166
      1          168
      2          171
      1          172
      2          173,175,176
      3          177
      1          178,179,181,182,188,189,193,194,197,200,202
      1          204,206,208,209,210
      2          212
      1          214,215,217,220
      2          223
      1          224,226
      3          232,234
      1          235
      2          239
      1          240,246,250
      2          251,252
      1          254
      2          256
      1          257,258,262,267,268,269
      2          270
      1          271
      3          274
      1          275,276,279
      2          282
      1          284,286,288,289
      3          293
      1          296,298,300

number correct: 161, total input: 300, per cent correct: 53.7
```

(c) Results after 904 Learning Trials

```
*****************************************
*****        Data Comparison        *****
*****   Tue Nov 28 14:01:42 1989    *****
*****************************************

network type: 1

expected values file: ad3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

*****************************************
*****        Data Comparison        *****
*****   Tue Nov 28 14:06:36 1989    *****
*****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1          41, 75,125,144,158,187,198,246
```

```
number correct: 292, total input: 300, per cent correct: 97.3

****************************************
*****        Data Comparison      *****
*****   Tue Nov 28 14:12:48 1989   *****
****************************************

network type: 1

expected values file: adr2.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

       1           14, 19, 33, 50, 67, 69, 70, 71, 84, 88, 91
       1           93,107
       2           108
       1           121,130,133,148,149,160,169
       2           172
       1           176,179
       2           201,207
       1           212,213,238
       2           242
       1           261,266
       2           281
       1           290,291

number correct: 265, total input: 300, per cent correct: 88.3

****************************************
*****        Data Comparison      *****
*****   Tue Nov 28 14:16:56 1989   *****
****************************************

network type: 1

expected values file: adr3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

       1            2,  5,  6,  8, 11, 26, 28, 30
       3           33,
       1           38, 40, 42
       2           44
       1           45, 48, 51, 52, 57, 59
       2           61
       1           62, 68, 72, 76
       2           77
       1           84
       2           88
       1           93
       2           94
       1           95,102,104,117,118
       2           122
       1           129,131,132,137,138
       2           145
       1           151,153
       2           157,158
       1           164,166,169,172,175,176,177
       2           179
       1           182,185,187
```

```
        2            188
        1            190,197,202,206,211,217,220,225,230,231,232
        1            236,238,241,246
        2            248
        1            255,260,261,263,265,268,281,283,289,291
        2            295
        1            296,297,298,299

number correct: 212, total input: 300, per cent correct: 70.7
```

(d) Results after 1205 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 14:28:24 1989   *****
****************************************

network type: 1

expected values file: ad4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 14:32:06 1989   *****
****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

        1             41, 75,187,198,246

number correct: 295, total input: 300, per cent correct: 98.3

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 14:35:52 1989   *****
****************************************

network type: 1

expected values file: adr2.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

        1             14,
        2             33
        1             50, 69, 70, 71, 84, 88, 91, 93,107
        2            108
        1            121,133,148,149,172,176
        2            201,207
        1            213,238
        2            242
        1             266
        2             281

number correct: 275, total input: 300, per cent correct: 91.7

*****************************************
*****          Data Comparison      *****
*****     Tue Nov 28 14:40:22 1989  *****
*****************************************

network type: 1

expected values file: adr3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

        1              2,  6,  8, 23, 26, 28, 30, 33, 40, 42
        2             44,
        1             45, 48, 52, 59, 60
        2             61
        1             62, 72, 75, 76, 77, 84
        2             88
        1             93
        2             94
        1             95,102,117
        2            122
        1            131,132,137
        2            138,145
        1            157,158,169,172,175,176,177.
        2            179
        1            182
        2            188
        1            190,197,202,206,211,216,217,220,225,230,231
        1            232,236,238,241,246,248,255,260,261,263,268
        1            281,283,290,291
        2            295
        1            296,297,298,299

number correct: 224, total input: 300, per cent correct: 74.7

*****************************************
*****          Data Comparison      *****
*****     Tue Nov 28 14:44:30 1989  *****
*****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

        1              2,  4, 12, 17, 19, 23, 29, 30, 33, 34
        3             35
        2             36
        1             37, 38, 43, 44
        2             45
        1             57, 61, 68, 70
        2             71
        1             72, 74, 75, 78
        3             79
```

```
      1           80
      2           82
      1           86
      2           87
      1           88, 89, 95, 98,102
      2          103,106
      1          110,120,122,127
      2          128,132
      1          133,134,142,146,151,153,156,157,165,166,168
      2          171
      1          172,173,175
      2          176
      1          177,179,181,182,188,193,194,197
      2          200
      1          202,206,208,209
      2          212
      1          214,215,223,224,226,228
      2          232
      1          234,235,239,240,246,251,252
      2          256
      1          257,258,269
      2          270
      1          274,275,282,284,286,288,289,293,296,298

number correct: 197, total input: 300, per cent correct: 65.7
```

(e) Results after 1506 Learning Trials

```
****************************************
*****       Data Comparison       *****
*****   Tue Nov 28 14:56:26 1989  *****
****************************************

network type: 1

expected values file: ad5.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****       Data Comparison       *****
*****   Tue Nov 28 14:59:56 1989  *****
****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****       Data Comparison       *****
*****   Tue Nov 28 15:03:54 1989  *****
****************************************

network type: 1

expected values file: adr2.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000
```

```
Number of Errors  Record Number
  Per Image

       1           14, 33, 70, 71, 88, 91, 93,107
       2          108
       1          121,133,148,172
       2          201
       1          207,213,238
       2          242
       1          266
       2          281

number correct: 280, total input: 300, per cent correct: 93.3

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 15:07:38 1989   *****
****************************************

network type: 1

expected values file: adr3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

       1            2,  6,  8, 26, 28, 30
       2           33
       1           40, 42
       2           44
       1           45, 48
       2           61
       1           64, 72, 75, 76, 77, 84
       2           88
       1           93
       2           94
       1           95,102
       2          122
       1          129,131,132,138
       2          145
       1          157,158,169,172,175,176,177,182
       2          188
       1          202,206,209,211,217,220,225,231,236,238,241
       1          246
       2          248
       1          255,260,261,263,283,291
       2          295
       1          298

number correct: 240, total input: 300, per cent correct: 80.0

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 15:11:28 1989   *****
****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image
```

```
        1          2,  4, 12, 17, 19, 23, 29, 30, 34
        3         35
        2         36
        1         37, 38, 43, 44, 45, 57, 61, 68, 70
        2         71
        1         72, 74, 75,
        3         79
        1         80
        2         82, 86
        1         87, 88, 89, 95, 98
        2         103,106
        1         110,120,122,127
        2         128,
        1         132,134,142,146,148,151,153,156,157,165,166,168
        2         171
        1         172
        2         173
        1         174
        2         175
        1         176,177,179,181,182,197
        2         200
        1         202,204,206,208,209,212,214,215,223,224,226,228
        2         232
        1         234,235
        2         239
        1         240,246,251,252
        2         256
        1         257,258,263,269
        2         270
        1         274,275,282,284,286,288,291,293,296,298

number correct: 199, total input: 300, per cent correct: 66.3
```

(f) Results after 2108 Learning Trials

```
****************************************
*****       Data Comparison      *****
*****   Tue Nov 28 15:27:00 1989  *****
****************************************

network type: 1

expected values file: ad3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****       Data Comparison      *****
*****   Tue Nov 28 15:30:32 1989  *****
****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****       Data Comparison      *****
*****   Tue Nov 28 15:34:18 1989  *****
****************************************
```

```
network type: 1

expected values file: adr2.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000


Number of Errors  Record Number
  Per Image

      1            14, 70, 71, 88, 93,107,108,121,133,148,172
      2           201
      1           207,238,242,266
      2           281

number correct: 283, total input: 300, per cent correct: 94.3

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 15:38:14 1989   *****
****************************************

network type: 1

expected values file: adr3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1             2,  6, 26, 28, 30
      2           33
      1           40, 42
      2           44
      1           45
      2           48
      1           61, 64, 72, 75, 76, 77, 84
      2           88
      1           93
      2           94
      1           95, 102
      2           122
      1           129,131,132
      2           138,145
      1           157,158,169,172,175,177,182
      2           188
      1           202,206,209,225,231,236,238,241,246
      2           248
      1           255,260,261,263,283,291
      2           295

number correct: 246, total input: 300, per cent correct: 82.0

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 15:42:16 1989   *****
****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000
```

```
Number of Errors  Record Number
  Per Image

      1            2, 4, 19, 23, 29, 30, 34
      3           35
      2           36
      1           37, 43, 44, 45, 57, 61, 68
      2           71
      1           72, 74
      3           79
      1           80, 82, 86, 87, 88, 89, 95, 98
      2           103,106
      1           110,120,122,127,128,132,134,142,146,151
      1           153,156,157,165,166,171,172
      2           173,175,176
      1           177,179,181,182,188,194,197
      2           200
      1           202,204,206,208,209,212,214,215,223,224,226,228
      2           232
      1           234,235
      2           239
      1           246,251,252
      2           256
      1           257,258,263,269
      2           270
      1           271,274,282,284,286,291,293,296,298

number correct: 208, total input: 300, per cent correct: 69.3
```

(g) Results after 2710 Learning Trials

```
*****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 15:55:56 1989   *****
*****************************************

network type: 1

expected values file: ad1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

*****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 16:00:00 1989   *****
*****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

*****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 16:04:22 1989   *****
*****************************************

network type: 1

expected values file: adr2.nni
```

```
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1            14, 71, 88,107,108,121,133,134,148,172
      2           201
      1           207,238,266
      2           281

number correct: 285, total input: 300, per cent correct: 95.0

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 16:08:06 1989   *****
****************************************

network type: 1

expected values file: adr3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1            2,  6, 26, 28
      2           33
      1           40, 42
      2           44
      1           45
      2           48
      1           60, 61, 64, 72, 75, 76, 77, 84
      2           88
      1           93
      2           94
      1           95, 102
      2           122
      1           129,131,132
      2           138,145
      1           157,158,169,172,175,177,182,188,202,206,209
      1           225,231,236,238,241,246
      2           248
      1           255,260,261,263,283,291
      2           295

number correct: 246, total input: 300, per cent correct: 82.0

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 16:11:52 1989   *****
****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1            2,  4, 19, 23, 29, 30, 34
      3           35
```

```
2          36
1          37, 38, 43, 44, 45, 61, 68
2          71
1          74
3          79
1          80
2          82
1          86, 87, 88, 89, 95, 98
2         103,106
1         110,120,127,128,132,134,142,146,151,153
1         156,157,165,166,172,173,174
2         175,176
1         177,179,181,182,188,194
2         200
1         202,204,206,208,209,212,214,215,223,224,226,228
2         232
1         234,235
2         239
1         246,251,252
2         256
1         257,258,263,269
2         270
1         271,274,282,284,286,291,293,296,298

number correct: 211, total input: 300, per cent correct: 70.3
```

(h) Results after 3312 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 16:25:54 1989   *****
****************************************

network type: 1

expected values file: ad5.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 16:29:26 1989   *****
****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****        Data Comparison       *****
*****   Tue Nov 28 16:33:02 1989   *****
****************************************

network type: 1

expected values file: adr2.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000
```

```
Number of Errors  Record Number
  Per Image

      1            14, 70, 71, 88,107,108,121,133,134,148,172
      2           201
      1           207,238
      2           281

number correct: 285, total input: 300, per cent correct: 95.0

****************************************
*****       Data Comparison       *****
*****   Tue Nov 28 16:36:54 1989  *****
****************************************

network type: 1

expected values file: adr3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1            2,  6, 26, 28
      2           33
      1           40, 42
      2           44
      1           45
      2           48
      1           60, 61, 64, 72, 75, 76, 77, 84
      2           88
      1           93
      2           94
      1           95, 102
      2           122
      1           129,131,132
      2           138,145
      1           158,169,172,175,177,182,188,202,206,209,225
      1           231,236,238,241,246
      2           248
      1           255,260,261,263,283,291
      2           295

number correct: 247, total input: 300, per cent correct: 82.3

****************************************
*****       Data Comparison       *****
*****   Tue Nov 28 16:40:42 1989  *****
****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1            2,  4, 19, 23, 30, 34
      3           35
      2           36, 37
      1           38, 43, 44, 45, 54, 61, 68
      2           71
      1           74
```

```
        3               79
        1               80
        2               82
        1               86, 87, 88, 89, 95, 98
        2               103,106
        1               110,120,127,128,132,134,142,146,151,153
        1               156,157,165,166,173,174
        2               175,176
        1               177,179,181,182,188,194
        2               200
        1               202,204,206,208,209,212,214,215,223,224,226,228
        2               232
        1               234,235
        2               239
        1               246,251,252
        2               256
        1               257,258,263,269
        2               270
        1               271,274,282,284,286,291,293,296,298

number correct: 212, total input: 300, per cent correct: 70.7
```

(i) Results after 3914 Learning Trials

```
****************************************
*****         Data Comparison      *****
*****   Wed Nov 29 09:36:56 1989   *****
****************************************

network type: 1

expected values file: ad4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****         Data Comparison      *****
*****   Wed Nov 29 09:40:30 1989   *****
****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****         Data Comparison      *****
*****   Wed Nov 29 09:44:20 1989   *****
****************************************

network type: 1

expected values file: adr2.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

     1             14, 39, 70, 71, 88,107,108,121,133,134,148
```

```
      2          201
      1          207,238
      2          281

number correct: 285, total input: 300, per cent correct: 95.0

****************************************
*****       Data Comparison        *****
*****   Wed Nov 29 09:48:18 1989   *****
****************************************

network type: 1

expected values file: adr3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1           2,  6, 26, 28, 33, 40, 42
      2          44
      1          45, 48, 60, 61, 64, 72, 75, 76, 77, 84
      2          88
      1          93
      2          94
      1          95, 102
      2          122
      1          129,131,132
      2          138,145
      1          158,169,172,175,177,182,188,202,206,209,225
      1          231,236,238,241,246
      2          248
      1          255,260,261,263,283,291
      2          295

number correct: 247, total input: 300, per cent correct: 82.3

****************************************
*****       Data Comparison        *****
*****   Wed Nov 29 09:53:24 1989   *****
****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1           2,  4,
      2          23
      1          30, 34
      3          35
      2          36, 37
      1          38, 43, 44, 45, 54, 61, 68
      2          71
      1          74
      3          79
      1          80
      2          82
      1          86, 87, 88, 89, 95, 98
      2          103,106
      1          110,120,127,128,132,134,142,146,151,153
```

```
        1          156,157,165,166,173,174
        2          175,176
        1          177,179,181,182,188,194
        2          200
        1          204,206,208,209,212,214,215,216,223,224,226,228
        2          232
        1          234,235
        2          239
        1          246,251,252
        2          256
        1          257,258,263,269
        2          270
        1          271,274,282,284,286,291,293,296,298

number correct: 213, total input: 300, per cent correct: 71.0
```

(j) Results after 4516 Learning Trials

```
****************************************
*****       Data Comparison       *****
*****  Wed Nov 29 10:10:02 1989   *****
****************************************

network type: 1

expected values file: ad5.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****       Data Comparison       *****
*****  Wed Nov 29 10:14:10 1989   *****
****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****       Data Comparison       *****
*****  Wed Nov 29 10:17:58 1989   *****
****************************************

network type: 1

expected values file: adr2.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Record Number  Number of Errors
Number of Errors  Record Number
  Per Image

        1           14, 39, 70, 71, 88,107,108,121,133,134,148
        2          201
        1          207,238
        2          281

number correct: 285, total input: 300, per cent correct: 95.0
```

```
****************************************
*****       Data Comparison       *****
*****  Wed Nov 29 10:21:54 1989   *****
****************************************

network type: 1

expected values file: adr3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1             2,  6, 26, 28, 33, 40, 42
      2            44
      1            45, 48, 57, 60, 61, 64, 72, 75, 76, 77, 84
      2            88
      1            93
      2            94
      1            95, 102
      2           122
      1           129,131,132
      2           138,145
      1           158,169,172,175,177,182,188,202,206,209,225
      1           231,236,238,241,246
      2           248
      1           255,260,261,263,283,291
      2           295

number correct: 247, total input: 300, per cent correct: 82.3

****************************************
*****       Data Comparison       *****
*****  Wed Nov 29 10:25:46 1989   *****
****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  Per Image

      1             2,  4,
      2            23
      1            30, 34
      3            35
      2            36, 37
      1            38, 43, 44, 45, 54, 61, 68
      2            71
      1            74
      2            79
      1            80
      2            82
      1            86, 87, 88, 89, 95, 98
      2           103,106
      1           110,120,127,128,132,134,142,146,151,153
      1           156,157,165,166,173,174
      2           175,176
      1           177,179,181,182,188,194
      2           200
      1           204,206,208,209,212,214,215,216,223,224,226,228
```

```
        2         232
        1         234,235
        2         239
        1         246,251,252
        2         256
        1         257,258,263,269
        2         270
        1         271,274,282,284,286,291,293,296,298

number correct: 213, total input: 300, per cent correct: 71.0
```

D.2 Hamming Network

D.2.1 Data Generation Logs (Training Files)

```
****************************************
*****        Data Generation      *****
*****   Thu Nov 30 10:34:22 1989  *****
****************************************

network type: 5

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: hamming.nni

binary: no              bipolar: yes
continuous: no          training required: yes
randomize records: no

random seed:        0
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 1

order of images for data set: 0
  0   1   2   3   4   5   6   7   8   9
```

D.2.2 Data Generation Logs (Testing Files) and Test Results Logs

```
****************************************
*****       Data Comparison       *****
*****  Thu Nov 30 10:41:42 1989   *****
****************************************

network type: 5

expected values file: hamming.nni
actual values file: hamming.nno

error tolerance during comparison: 0.000000

number correct: 10, total input: 10, per cent correct: 100.0

****************************************
*****       Data Generation       *****
*****  Thu Nov 30 10:44:04 1989   *****
****************************************

network type: 5

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: har1.nni

binary: no                 bipolar: yes
continuous: no             training required: yes
randomize records: yes

random seed:      8767
number of pixels to randomize in peaks: 3, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number       order of images in data set
     0             1   9   8   4   7   2   3   6   5   0
     1             8   6   1   3   5   4   0   7   9   2
     2             9   7   1   6   5   0   2   3   8   4
     3             9   3   7   4   6   2   8   5   1   0
     4             6   5   2   0   3   4   7   8   9   1
     5             3   7   9   0   1   2   4   5   6   8
     6             2   0   6   9   3   5   1   7   4   8
     7             5   4   0   1   6   8   3   7   2   9
     8             1   5   0   8   7   4   2   3   6   9
     9             0   4   9   8   5   2   3   7   1   6
    10             3   6   1   5   7   4   2   8   0   9
    11             7   6   8   0   9   1   2   5   4   3
    12             9   0   2   1   5   8   6   7   3   4
    13             2   0   1   4   3   6   5   9   8   7
    14             8   6   5   7   9   1   0   2   3   4
    15             0   2   8   4   1   7   9   6   5   3
    16             6   3   5   1   8   9   7   4   0   2
    17             4   7   5   9   8   1   2   6   0   3
    18             6   9   0   5   4   1   3   8   2   7
    19             5   3   6   2   9   8   0   4   7   1
    20          9   1   5   0   6   4   2   8   3   7
    21          7   0   6   4   5   1   8   3   9   2
    22          2   1   7   5   0   6   3   9   8   4
    23          2   7   0   8   6   5   9   1   4   3
    24          5   7   3   8   9   6   1   2   0   4
    25          6   2   1   8   5   9   0   7   4   3
    26          7   1   9   2   3   0   5   6   8   4
    27          8   0   3   5   1   4   7   9   6   2
    28          0   4   6   8   7   1   5   3   2   9
    29          5   9   4   7   2   3   6   0   1   8
****************************************
*****        Data Comparison       *****
*****   Thu Nov 30 10:52:00 1989   *****
****************************************

network type: 5

expected values file: har1.nni
actual values file: hamming.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****        Data Generation       *****
*****   Thu Nov 30 10:54:12 1989   *****
****************************************

network type: 5

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: har2.nni

binary: no                 bipolar: yes
continuous: no             training required: yes
randomize records: yes

random seed:     1737
number of pixels to randomize in peaks: 6, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number      order of images in data set
     0          6   1   4   8   3   5   7   0   2   9
     1          2   1   9   8   3   4   0   5   7   6
     2          0   9   6   7   5   2   8   4   1   3
     3          6   3   9   4   2   0   8   1   7   5
     4          3   5   9   2   0   4   8   6   1   7
     5          2   0   9   4   8   6   1   7   3   5
     6          4   8   3   5   9   2   7   1   6   0
     7          0   7   1   5   2   3   6   9   4   8
     8          0   7   4   6   5   8   2   3   1   9
     9          7   6   4   5   9   1   2   0   8   3
    10          0   8   6   1   7   4   9   5   3   2
    11          9   0   2   8   6   5   3   4   7   1
    12          4   8   7   9   2   5   3   0   1   6
   13          7   4   1   0   5   3   8   2   9   6
   14          1   4   2   0   9   3   5   8   7   6
   15          1   2   9   3   8   0   6   7   4   5
   16          4   6   5   8   9   0   7   3   1   2
   17          6   2   4   1   3   5   0   9   8   7
   18          6   4   0   8   7   5   9   1   2   3
   19          4   6   9   0   5   1   8   3   7   2
   20          4   3   8   5   2   0   6   7   1   9
   21          3   4   2   9   0   5   8   7   1   6
   22          3   0   7   4   5   8   2   1   9   6
   23          1   9   8   5   6   2   0   3   7   4
   24          2   7   8   1   9   0   4   3   5   6
   25          2   8   4   0   3   7   5   1   6   9
   26          4   0   3   9   7   6   5   8   1   2
   27          3   4   0   1   8   5   6   9   2   7
   28          6   7   3   0   5   2   8   9   1   4
   29          5   8   1   9   6   7   0   4   2   3

****************************************
*****       Data Comparison        *****
*****   Thu Nov 30 11:01:16 1989   *****
****************************************

network type: 5

expected values file: har2.nni
actual values file: hamming.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****       Data Generation        *****
*****   Thu Nov 30 11:03:16 1989   *****
****************************************

network type: 5

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: har3.nni

binary: no                bipolar: yes
continuous: no            training required: yes
randomize records: yes

random seed:      2711
number of pixels to randomize in peaks: 9, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number       order of images in data set
    0          7   0   2   5   6   4   3   8   9   1
    1          1   7   6   4   9   3   2   8   5   0
    2          4   5   9   0   8   3   1   2   6   7
    3          7   4   8   6   1   9   3   2   5   0
    4          6   2   0   8   3   1   9   4   5   7
    5              6    8    5    2    1    0    4    7    3    9
    6              4    7    9    1    2    3    8    5    6    0
    7              8    2    3    5    7    6    4    1    9    0
    8              6    2    9    3    1    5    0    7    8    4
    9              5    4    9    3    2    6    8    1    7    0
   10              8    7    4    2    3    5    0    1    6    9
   11              0    9    2    7    1    8    6    5    3    4
   12              9    2    4    6    1    3    8    7    5    0
   13              5    9    3    1    0    8    7    2    4    6
   14              1    4    2    5    3    9    8    0    7    6
   15              8    3    5    9    7    4    2    1    6    0
   16              0    4    6    9    5    2    7    3    8    1
   17              8    2    5    1    4    7    3    9    6    0
   18              8    0    9    3    7    1    4    5    2    6
   19              1    0    5    6    8    4    9    2    7    3
   20              4    8    5    6    2    3    0    1    9    7
   21              2    0    8    6    4    9    5    3    1    7
   22              7    3    9    5    6    0    8    1    2    4
   23              0    8    9    5    2    7    3    6    1    4
   24              1    4    5    2    7    0    8    6    3    9
   25              2    4    8    9    7    3    0    6    5    1
   26              1    8    3    7    0    9    4    6    5    2
   27              9    1    5    6    7    0    3    4    8    2
   28              4    1    3    6    0    5    2    8    7    9
   29              2    3    0    9    7    6    4    1    5    8

****************************************
*****         Data Comparison      *****
*****    Thu Nov 30 11:17:10 1989  *****
****************************************

network type: 5

expected values file: har3.nni
actual values file: hamming.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****         Data Generation      *****
*****    Thu Nov 30 11:19:42 1989  *****
****************************************

network type: 5

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: har4.nni

binary: no                 bipolar: yes
continuous: no             training required: yes
randomize records: yes

random seed:     5929
number of pixels to randomize in peaks: 12, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21
```

D. HAMMING LOGS D.

```
number of data sets generated: 30
data set number        order of images in data set
      0             7   1   5   4   8   6   9   2   3   0
      1             1   6   0   5   3   8   9   4   2   7
      2             9   3   5   1   0   4   7   6   2   8
      3             5   1   3   2   8   9   7   6   0   4
      4             3   5   1   0   4   2   6   9   8   7
      5             3   8   7   4   2   9   5   1   0   6
      6             9   7   5   0   2   3   8   6   4   1
      7             1   5   3   8   4   0   7   9   6   2
      8             5   4   6   8   7   2   3   1   9   0
      9             8   0   4   1   7   3   2   6   9   5
     10             7   8   2   6   4   5   1   9   0   3
     11             9   7   4   1   0   5   2   8   3   6
     12             5   9   2   7   1   3   0   6   8   4
     13             7   9   8   6   0   2   1   5   4   3
     14             0   9   5   1   8   7   3   2   6   4
     15             5   8   3   2   7   0   1   9   4   6
     16             6   5   1   2   0   4   7   3   8   9
     17             7   4   9   0   5   1   3   6   2   8
     18             3   6   9   8   1   2   7   0   4   5
     19             2   7   4   1   0   9   5   3   8   6
     20             3   7   2   6   8   5   4   0   1   9
     21             1   2   3   0   5   7   6   4   9   8
     22             9   0   2   8   7   3   6   1   4   5
     23             2   5   3   4   6   1   0   9   8   7
     24             5   8   4   1   9   6   3   2   7   0
     25             3   4   8   9   2   5   6   1   0   7
     26             8   5   9   4   1   3   6   7   0   2
     27             3   2   5   4   0   9   1   6   7   8
     28             2   7   9   8   4   1   3   5   6   0
     29             8   0   6   2   9   1   5   3   4   7

****************************************
*****         Data Comparison      *****
*****   Thu Nov 30 11:26:48 1989   *****
****************************************

network type: 5

expected values file: har4.nni
actual values file: hamming.nno

error tolerance during comparison: 0.000000

number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****         Data Generation      *****
*****   Thu Dec 21 11:37:56 1989   *****
****************************************

network type: 5

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: har5.nni

binary: no               bipolar: yes
continuous: no           training required: yes
randomize records: yes

random seed:      9910
number of pixels to randomize in peaks: 48, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)
```

```
data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

      0               0   6   2   7   8   5   1   4   9   3
      1               6   8   7   2   5   0   1   9   3   4
      2               1   7   6   9   0   2   4   5   3   8
      3               7   3   9   8   4   0   5   1   6   2
      4               4   6   8   3   9   7   1   2   5   0
      5               0   7   8   2   3   4   5   6   1   9
      6               5   6   2   9   1   8   7   4   3   0
      7               8   1   5   2   3   9   0   4   7   6
      8               2   3   5   7   9   8   6   4   0   1
      9               1   0   7   4   9   2   5   6   3   8
     10               6   2   9   5   1   7   4   8   0   3
     11               4   6   2   8   9   1   7   3   5   0
     12               5   4   2   9   6   0   3   1   7   8
     13               2   5   9   4   0   6   1   7   8   3
     14               7   6   2   4   1   0   3   5   8   9
     15               7   8   1   0   2   9   6   3   5   4
     16               3   8   4   1   7   0   6   5   2   9
     17               9   8   5   3   1   2   0   6   7   4
     18               9   7   1   6   8   5   3   2   4   0
     19               9   0   8   7   2   1   3   6   4   5
     20               6   9   3   0   5   4   2   1   7   8
     21               6   8   9   1   2   0   3   7   4   5
     22               9   7   3   5   2   8   6   0   4   1
     23               0   4   3   8   9   5   2   7   6   1
     24               1   2   4   8   7   9   0   6   5   3
     25               5   2   3   7   8   0   9   1   6   4
     26               7   4   5   2   6   0   3   1   8   9
     27               5   1   9   0   3   4   2   6   7   8
     28               9   0   8   7   5   4   1   6   3   2
     29               0   3   5   4   1   6   7   8   2   9

****************************************
*****         Data Comparison      *****
*****   Thu Dec 21 11:45:06 1989   *****
****************************************

network type: 5

expected values file: har5.nni
actual values file: hamming.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

       2            22
number correct: 299, total input: 300, per cent correct: 99.7

****************************************
*****         Data Generation      *****
*****   Thu Dec 21 11:46:30 1989   *****
****************************************

network type: 5
```

```
input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: har6.nni

binary: no                bipolar: yes
continuous: no            training required: yes
randomize records: yes

random seed:     1737
number of pixels to randomize in peaks: 65, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

      0             6   2   4   7   9   3   5   8   1   0
      1             1   0   5   3   7   2   9   4   8   6
      2             2   5   8   7   6   0   9   3   1   4
      3             4   1   9   2   7   6   8   5   3   0
      4             8   9   0   1   7   3   5   4   2   6
      5             5   9   8   1   2   4   7   0   3   6
      6             8   2   7   6   1   3   0   9   5   4
      7             7   3   4   2   6   8   5   9   1   0
      8             4   2   0   8   3   1   6   5   9   7
      9             8   9   5   6   4   0   3   2   7   1
     10             6   1   9   3   2   4   7   0   5   8
     11             6   2   0   7   3   1   4   8   5   9
     12             6   2   5   4   1   9   0   3   8   7
     13             7   2   9   5   8   0   6   4   3   1
     14             7   5   6   9   4   8   2   3   1   0
     15             3   0   4   5   2   9   8   6   7   1
     16             1   6   8   9   7   2   5   0   3   4
     17             7   2   6   5   1   4   3   9   8   0
     18             9   6   1   4   8   0   2   7   5   3
     19             2   5   9   7   1   6   0   8   3   4
     20             2   0   6   9   3   1   7   4   5   8
     21             1   4   5   0   7   2   8   6   9   3
     22             1   6   5   4   2   9   3   8   7   0
     23             0   3   9   2   7   4   1   6   8   5
     24             0   2   9   4   3   7   1   5   6   8
     25             9   1   0   8   7   3   6   4   5   2
     26             2   7   8   4   0   1   5   6   9   3
     27             5   9   8   6   0   7   3   4   2   1
     28             5   8   9   3   2   1   6   4   0   7
     29             4   6   2   8   0   7   5   1   9   3

*****************************************
*****        Data Comparison       *****
*****   Thu Dec 21 11:51:58 1989    *****
*****************************************

network type: 5

expected values file: har6.nni
actual values file: hamming.nno
```

```
error tolerance during comparison: 0.000000


number correct: 300, total input: 300, per cent correct: 100.0

*****************************************
*****        Data Generation        *****
*****   Thu Dec 21 11:54:02 1989   *****
*****************************************

network type: 5

input file: image
   images:    10  rows:     6  columns:    27  classes:    10
output file: har7.nni

binary: no               bipolar: yes
continuous: no           training required: yes
randomize records: yes

random seed:      1537
number of pixels to randomize in peaks: 81, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

      0              5   1   9   3   0   6   7   2   4   8
      1              7   4   5   3   2   8   1   6   0   9
      2              4   6   2   0   1   3   9   5   8   7
      3              8   3   0   6   5   9   4   1   7   2
      4              9   3   1   6   4   5   7   8   0   2
      5              9   6   8   0   4   7   1   5   2   3
      6              1   4   0   7   2   3   5   6   9   8
      7              4   9   0   6   5   7   8   2   3   1
      8              6   5   4   7   3   8   9   1   2   0
      9              3   8   5   9   6   7   0   1   4   2
     10              3   6   2   0   4   1   9   5   8   7
     11              2   9   6   5   4   0   1   7   3   8
     12              3   5   8   7   4   1   9   2   0   6
     13              5   0   4   7   8   1   2   6   3   9
     14              2   6   4   7   1   5   3   0   9   8
     15              4   5   7   9   0   8   2   3   6   1
     16              3   5   2   0   6   1   9   4   7   8
     17              7   2   4   0   8   5   3   1   6   9
     18              7   8   1   0   9   6   5   4   2   3
     19              2   8   5   4   9   6   7   3   0   1
     20              7   3   8   0   2   4   9   6   5   1
     21              5   6   8   7   9   4   0   2   1   3
     22              8   5   6   3   7   2   4   9   1   0
     23              0   7   2   4   3   8   5   1   6   9
     24              2   6   8   9   0   3   1   5   4   7
     25              7   5   0   6   3   8   4   9   1   2
     26              5   8   2   9   4   6   7   3   1   0
     27              1   9   8   7   5   4   0   6   3   2
     28              1   4   5   2   6   3   0   9   8   7
     29              4   3   7   0   6   5   9   2   8   1
```

```
******************************************
*****        Data Comparison        *****
*****   Thu Dec 21 11:59:20 1989    *****
******************************************

network type: 5

expected values file: har7.nni
actual values file: hamming.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      2        88,120,179,251
number correct: 296, total input: 300, per cent correct: 98.7

******************************************
*****        Data Generation        *****
*****   Thu Dec 21 12:00:44 1989    *****
******************************************

network type: 5

input file: image
   images:    10   rows:     6   columns:   27   classes:    10
output file: har8.nni

binary: no                 bipolar: yes
continuous: no             training required: yes
randomize records: yes

random seed:      5929
number of pixels to randomize in peaks: 100, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

      0            7   3   5   1   9   8   2   6   4   0
      1            7   2   4   8   9   6   1   0   3   5
      2            2   5   3   7   9   8   4   1   0   6
      3            2   8   1   3   9   4   6   7   5   0
      4            9   6   2   0   5   4   7   3   1   8
      5            4   0   6   3   7   9   1   5   2   8
      6            7   5   4   8   3   2   1   0   6   9
      7            7   0   4   1   2   5   3   8   9   6
      8            3   9   4   2   6   5   1   0   8   7
      9            6   1   9   7   5   4   0   3   2   8
     10            0   6   7   3   5   9   4   2   1   8
     11            7   0   8   2   1   3   5   9   6   4
     12            2   5   3   0   6   1   4   9   8   7
     13            1   2   4   8   6   5   9   0   3   7
     14            3   1   2   5   7   8   9   4   6   0
     15            5   1   4   3   8   7   6   0   9   2
     16               6   0   2   1   8   4   3   7   5   9
     17               4   5   7   9   6   0   8   1   2   3
     18               8   0   2   6   1   9   7   3   4   5
     19               0   2   8   7   6   4   5   1   9   3
     20               3   9   2   6   8   7   0   4   1   5
     21               5   8   6   3   4   7   0   2   1   9
     22               8   7   2   6   1   9   3   5   0   4
     23               7   8   0   5   4   1   6   9   2   3
     24               6   0   7   4   9   2   5   8   3   1
     25               2   1   5   3   0   7   6   4   9   8
     26               2   6   0   5   9   4   3   8   1   7
     27               3   7   5   8   1   9   2   0   6   4
     28               2   6   5   1   0   9   3   8   4   7
     29               0   6   1   5   9   8   2   7   4   3

****************************************
*****         Data Comparison      *****
*****    Thu Dec 21 12:07:24 1989  *****
****************************************

network type: 5

expected values file: har8.nni
actual values file: hamming.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      2         1, 6, 16, 35, 37, 46, 48, 64, 69, 89, 90
      2        111,121,122,130,157,169,174,290
number correct: 281, total input: 300, per cent correct: 93.7

****************************************
*****         Data Generation      *****
*****    Thu Dec 21 12:08:48 1989  *****
****************************************

network type: 5

input file: image
   images:    10   rows:     6   columns:     27   classes:     10
output file: har9.nni

binary: no                bipolar: yes
continuous: no            training required: yes
randomize records: yes

random seed:     2711
number of pixels to randomize in peaks: 125, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number     order of images in data set

     0                7   5   6   2   9   0   4   3   1   8
```

```
 1          1  4  5  7  2  3  9  8  6  0
 2          1  2  7  9  6  5  0  8  3  4
 3          5  7  0  4  8  3  2  9  6  1
 4          6  1  0  5  4  7  2  8  9  3
 5          6  0  9  3  8  7  4  2  5  1
 6          8  4  7  1  0  9  3  2  5  6
 7          8  3  1  5  0  7  9  2  6  4
 8          2  5  3  0  4  8  9  1  6  7
 9          3  9  6  1  4  0  2  7  8  5
10          2  4  0  9  8  6  5  7  1  3
11          2  5  1  3  6  9  8  0  7  4
12          0  4  7  1  5  8  9  2  6  3
13          7  2  6  9  5  3  4  8  0  1
14          1  9  8  2  7  0  4  6  5  3
15          2  7  8  1  4  5  6  3  9  0
16          8  4  5  2  3  1  0  9  6  7
17          9  0  7  1  6  3  2  4  5  8
18          4  3  8  2  6  1  0  5  7  9
19          4  3  6  0  7  9  1  8  2  5
20          8  5  2  6  7  0  3  1  9  4
21          1  8  7  2  3  5  9  4  0  6
22          6  0  5  3  7  8  2  1  9  4
23          2  1  6  3  0  9  8  4  5  7
24          1  6  5  7  2  9  4  8  3  0
25          0  4  8  6  3  9  7  5  2  1
26          5  4  7  6  2  1  8  0  9  3
27          2  3  6  5  8  9  1  7  4  0
28          6  7  3  5  1  8  9  4  0  2
29          8  7  6  5  2  4  9  1  3  0

****************************************
*****         Data Comparison      *****
*****    Thu Dec 21 12:14:00 1989  *****
****************************************

network type: 5

expected values file: har9.nni
actual values file: hamming.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      2       1,  2,  3,  5,  7, 14, 16, 17, 19, 24, 31
      2      34, 35, 37, 38, 41, 42, 44, 45, 49, 51, 53
      2      55, 63, 64, 70, 71, 78, 85, 87, 91, 94, 97
      2      98, 99,100,105,108,112,115,117,122,123,127
      2     130,133,134,135,136,138,142,147,154,159,162
      2     163,164,170,171,173,176,179,185,188,192,193
      2     195,197,199,201,204,208,209,213,214,217,221
      2     223,229,233,234,236,239,243,256,264,269,270
      2     278,281,283,286,288,291,295,297
number correct: 204, total input: 300, per cent correct: 68.0
```

D.3 BAM Network

D.3.1 Data Generation Logs (Training Files)

```
****************************************
*****       Data Generation        *****
*****   Fri Dec  1 13:51:24 1989   *****
****************************************

network type: 4

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bam.nni

binary: no              bipolar: yes
continuous: no          training required: yes
randomize records: no

random seed:        0
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

number of classes to randomize: 0
data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 1

order of images for data set: 0
  0   1   2   3   4   5   6   7   8   9
```

D.3.2 Data Generation Logs (Testing Files) and Test Results Logs

```
****************************************
*****        Data Comparison      *****
*****   Fri Dec  1 13:56:00 1989  *****
****************************************

network type: 4

expected values file: bam.nni
actual values file: bam.nno

error tolerance during comparison: 0.000000

Record Number  Number of Errors

       1              1
       .              .
       .              .
       .              .
      10              1
number correct: 0, total input: 10, per cent correct:  0.0

****************************************
*****        Data Comparison      *****
*****   Fri Dec  1 13:57:18 1989  *****
****************************************

network type: 4

expected values file: bam.nni
actual values file: bam.nno

error tolerance during comparison: 0.000000

Record Number  Number of Errors

       1              1
       3              1
       4              1
       6              1
       8              1
       9              1
      10              1
number correct: 3, total input: 10, per cent correct: 30.0

****************************************
*****        Data Generation      *****
*****   Fri Dec  1 13:59:22 1989  *****
****************************************

network type: 4

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bar1.nni

binary: no              bipolar: yes
continuous: no          training required: yes
randomize records: yes

random seed:     8767
number of pixels to randomize in peaks: 3, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

number of classes to randomize: 0
```

```
data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number        order of images in data set
     0              1   9   8   4   7   2   3   6   5   0
     1              8   6   1   3   5   4   0   7   9   2
     2              9   7   1   6   5   0   2   3   8   4
     3              9   3   7   4   6   2   8   5   1   0
     4              6   5   2   0   3   4   7   8   9   1
     5              3   7   9   0   1   2   4   5   6   8
     6              2   0   6   9   3   5   1   7   4   8
     7              5   4   0   1   6   8   3   7   2   9
     8              1   5   0   8   7   4   2   3   6   9
     9              0   4   9   8   5   2   3   7   1   6
    10              3   6   1   5   7   4   2   8   0   9
    11              7   6   8   0   9   1   2   5   4   3
    12              9   0   2   1   5   8   6   7   3   4
    13              2   0   1   4   3   6   5   9   8   7
    14              8   6   5   7   9   1   0   2   3   4
    15              0   2   8   4   1   7   9   6   5   3
    16              6   3   5   1   8   9   7   4   0   2
    17              4   7   5   9   8   1   2   6   0   3
    18              6   9   0   5   4   1   3   8   2   7
    19              5   3   6   2   9   8   0   4   7   1
    20              9   1   5   0   6   4   2   8   3   7
    21              7   0   6   4   5   1   8   3   9   2
    22              2   1   7   5   0   6   3   9   8   4
    23              2   7   0   8   6   5   9   1   4   3
    24              5   7   3   8   9   6   1   2   0   4
    25              6   2   1   8   5   9   0   7   4   3
    26              7   1   9   2   3   0   5   6   8   4
    27              8   0   3   5   1   4   7   9   6   2
    28              0   4   6   8   7   1   5   3   2   9
    29              5   9   4   7   2   3   6   0   1   8

****************************************
*****        Data Comparison       *****
*****   Fri Dec  1 14:07:14 1989   *****
****************************************

network type: 4

expected values file: bar1.nni
actual values file: bam.nno

error tolerance during comparison: 0.000000

Detailed error reporting disabled

number correct: 139, total input: 300, per cent correct: 46.3

****************************************
*****        Data Comparison       *****
*****   Fri Dec  1 14:39:12 1989   *****
****************************************

network type: 4

expected values file: bar1.nni
actual values file: bam.nno
```

```
error tolerance during comparison: 0.000000

Record Number  Number of Errors

       1              1
       2              1
       .              .
       .              .
       .              .
     299              1
     300              1
number correct: 0, total input: 300, per cent correct:  0.0

****************************************
*****       Data Generation        *****
*****   Fri Dec  1 14:42:08 1989   *****
****************************************

network type: 4

input file: image
   images:    10   rows:      6   columns:    27   classes:     10
output file: bar4.mni

binary: no                    bipolar: yes
continuous: no                training required: yes
randomize records: yes

random seed:      5929
number of pixels to randomize in peaks: 12, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

number of classes to randomize: 3
data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30
data set number         order of images in data set
      0               7   9   4   6   5   3   2   0   8   1
      1               1   0   8   3   7   9   5   4   6   2
      2               2   8   1   4   5   9   3   6   7   0
      3               1   7   5   3   9   0   6   2   4   8
      4               6   7   8   3   4   5   9   2   1   0
      5               9   1   5   3   6   4   8   7   2   0
      6               9   1   0   4   6   5   3   8   7   2
      7               1   5   4   9   7   8   6   2   0   3
      8               1   5   7   9   6   4   8   2   0   3
      9               2   3   8   4   0   9   7   5   6   1
     10               3   9   4   2   6   0   1   8   5   7
     11               9   5   8   7   0   4   3   2   6   1
     12               3   4   1   5   0   8   7   2   6   9
     13               3   5   2   6   9   4   1   0   7   8
     14               1   9   4   6   5   3   0   8   7   2
     15               2   9   5   6   8   3   7   0   1   4
     16               4   2   3   9   7   0   5   8   6   1
     17               7   0   8   6   1   9   2   4   5   3
     18               5   7   2   4   0   6   3   8   1   9
     19               5   6   4   8   1   9   3   0   2   7
     20               9   6   3   1   2   5   4   7   8   0
     21               8   2   4   9   7   6   1   0   3   5
     22               9   7   6   3   5   1   4   8   0   2
```

```
23          7   0   9   1   3   8   4   6   5   2
24          7   6   9   3   1   5   8   2   0   4
25          9   0   4   5   6   1   2   3   7   8
26          0   1   4   5   8   2   3   9   7   6
27          3   8   4   6   2   1   7   9   5   0
28          3   1   5   2   8   7   9   6   0   4
29          4   6   9   8   5   3   1   2   0   7

****************************************
*****        Data Comparison       *****
*****   Fri Dec  1 14:49:30 1989   *****
****************************************

network type: 4

expected values file: bar4.nni
actual values file: bam.nno

error tolerance during comparison: 0.000000

Detailed error reporting disabled

number correct: 20, total input: 300, per cent correct:  6.7

****************************************
*****        Data Comparison       *****
*****   Fri Dec  1 15:12:38 1989   *****
****************************************

network type: 4

expected values file: bar4.nni
actual values file: bam.nno

error tolerance during comparison: 0.000000

Record Number  Number of Errors

      1               1
      2               1
      .               .
      .               .
    299               1
    300               1
number correct: 0, total input: 300, per cent correct:  0.0
```

D.3.3 Data Generation Logs (Training Files)
Small Test File

```
*****************************************
*****        Data Generation       *****
*****   Fri Dec  1 13:37:58 1989   *****
*****************************************

network type: 4

input file: image.tst
   images:     3  rows:     2  columns:     4  classes:     3
output file: bamtst.nni

binary: no                bipolar: yes
continuous: no            training required: yes
randomize records: no

random seed:          0
number of pixels to randomize in peaks: 0, total pixels: 8
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

number of classes to randomize: 0
data minimum (or adjusted minimum): 1.000000
data maximum (or adjusted maximum): 17.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 009.0
level:   3, low value: 09.00, high value: 00013
level:   4, low value: 13.00, high value: 1.0e+21

number of data sets generated: 1

order of images for data set: 0
  0   1   2
```

D.3.4 Data Generation Logs (Testing Files) and Test Results Logs for Small Test File

```
*****************************************
*****        Data Comparison        *****
*****   Fri Dec  1 13:41:06 1989    *****
*****************************************

network type: 4

expected values file: bamtst.nni
actual values file: bam.nno

error tolerance during comparison: 0.000000

number correct: 3, total input: 3, per cent correct: 100.0

*****************************************
*****        Data Generation        *****
*****   Fri Dec  1 13:42:22 1989    *****
*****************************************

network type: 4

input file: image.tst
   images:     3  rows:      2  columns:     4  classes:     3
output file: bamtstr.nni

binary: no                bipolar: yes
continuous: no            training required: yes
randomize records: yes

random seed:      9910
number of pixels to randomize in peaks: 3, total pixels: 8
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

number of classes to randomize: 1
data minimum (or adjusted minimum): 1.000000
data maximum (or adjusted maximum): 17.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 009.0
level:   3, low value: 09.00, high value: 00013
level:   4, low value: 13.00, high value: 1.0e+21

number of data sets generated: 30
data set number       order of images in data set
     0            0   2   1
     1            1   0   2
     2            1   2   0
     3            2   1   0
     4            0   2   1
     5            0   2   1
     6            1   2   0
     7            1   0   2
     8            0   2   1
     9            2   0   1
    10            2   1   0
    11            2   0   1
    12            1   0   2
    13            0   2   1
    14            0   1   2
    15            0   1   2
    16            1   2   0
    17            0   2   1
    18            2   0   1
```

```
      19            0    1    2
      20            2    1    0
      21            2    1    0
      22            0    1    2
      23            1    2    0
      24            0    1    2
      25            1    0    2
      26            2    1    0
      27            1    2    0
      28            2    1    0
      29            0    2    1

****************************************
*****         Data Comparison      *****
*****    Fri Dec  1 13:44:18 1989  *****
****************************************

network type: 4

expected values file: bamtstr.nni
actual values file: bam.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

       1            1,  8,  9, 11, 13, 14, 16, 19, 22, 25, 30
       1           37, 39, 41, 43, 44, 46, 49, 52, 53, 54, 57
       1           58, 59, 60, 62, 63, 65, 71, 74, 75, 77, 79
       1           81, 85

number correct: 54, total input: 90, per cent correct: 60.0
```

D.4 Recirculation Network

D.4.1 Data Generation Logs (Training Files)

```
****************************************
*****        Data Generation       *****
*****   Mon Dec  4 13:56:52 1989   *****
****************************************

network type: 7

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: rec1.mni

binary: no                  bipolar: no
continuous: yes             training required: yes
randomize records: yes

random seed:     9910
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30
data set number        order of images in data set
     0               0   2   1   5   7   9   6   3   8   4
     1               6   5   0   7   2   8   3   9   1   4
     2               5   9   7   4   3   6   1   2   0   8
     3               9   1   3   7   0   8   2   5   4   6
     4               2   4   1   5   7   9   6   0   8   3
     5               4   8   0   9   3   2   7   6   5   1
     6               9   8   7   3   5   0   4   6   1   2
     7               8   7   1   0   3   5   9   6   4   2
     8               5   7   1   2   4   8   3   0   6   9
     9               1   0   9   2   6   7   5   8   3   4
    10               6   1   9   3   8   4   0   2   7   5
    11               9   5   4   8   1   0   3   6   7   2
    12               4   2   0   3   1   8   9   5   7   6
    13               7   0   5   9   3   6   2   1   8   4
    14               6   5   0   4   7   9   8   3   1   2
    15               5   0   1   4   8   7   9   6   2   3
    16               6   8   4   5   0   3   7   1   2   9
    17               7   3   5   8   6   9   4   2   0   1
    18               3   8   4   5   6   1   2   9   0   7
    19               6   1   4   5   8   9   0   7   2   3
    20               3   4   2   5   8   6   7   0   9   1
    21               6   0   1   4   2   5   7   9   8   3
    22               2   9   7   4   1   8   3   0   5   6
    23               6   9   5   8   2   7   0   4   3   1
    24               1   3   8   4   7   0   9   6   2   5
    25               4   1   7   2   5   6   0   8   3   9
    26               2   5   4   9   8   3   1   6   7   0
    27               1   0   8   9   3   6   4   2   5   7
    28               3   9   7   6   0   8   2   4   1   5
    29               9   8   7   4   0   3   5   1   6   2
```

```
*****************************************
*****        Data Generation        *****
*****   Mon Dec  4 13:54:46 1989    *****
*****************************************

network type: 7

input file: image
   images:     10   rows:      6   columns:     27   classes:     10
output file: rec2.mni

binary: no                bipolar: no
continuous: yes           training required: yes
randomize records: yes

random seed:     1576
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30
data set number      order of images in data set
     0           4   7   2   9   8   3   6   0   1   5
     1           1   9   2   3   0   5   4   7   8   6
     2           2   0   3   4   9   1   5   8   7   6
     3           8   0   3   2   4   9   7   6   5   1
     4           7   5   4   8   1   3   6   0   2   9
     5           8   9   2   7   5   1   0   3   4   6
     6           8   3   4   6   9   1   5   2   7   0
     7           1   2   5   6   0   8   3   9   4   7
     8           9   3   4   8   5   2   1   0   7   6
     9           3   7   9   1   0   8   5   6   4   2
    10           8   6   5   1   7   2   0   9   3   4
    11           4   9   6   8   0   2   3   7   1   5
    12           4   8   5   6   7   2   0   3   9   1
    13           0   4   7   8   9   6   1   3   5   2
    14           9   2   6   4   0   3   8   7   5   1
    15           2   4   3   5   6   8   7   0   9   1
    16           5   1   7   3   4   8   9   6   0   2
    17           5   7   9   0   3   1   2   6   4   8
    18           8   0   3   4   7   9   6   5   1   2
    19           6   8   0   7   3   4   5   2   9   1
    20           5   4   8   9   3   1   7   2   6   0
    21           9   3   2   6   1   7   5   0   4   8
    22           9   2   4   8   1   6   3   5   0   7
    23           2   1   8   9   0   4   7   6   3   5
    24           9   4   8   3   6   7   1   0   5   2
    25           3   8   2   1   5   7   6   4   0   9
    26           9   6   3   0   2   4   8   5   7   1
    27           8   4   2   6   3   1   5   0   9   7
    28           7   5   3   6   0   4   8   1   9   2
    29           8   6   4   9   7   1   0   5   2   3
```

```
****************************************
*****        Data Generation      *****
*****  Mon Dec  4 14:01:46 1989   *****
****************************************

network type: 7

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: rec3.nni

binary: no               bipolar: no
continuous: yes          training required: yes
randomize records: yes

random seed:     4589
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30
data set number      order of images in data set
     0           4   7   6   8   0   3   2   1   9   5
     1           4   2   9   5   0   8   6   7   1   3
     2           7   0   4   1   8   3   9   5   2   6
     3           4   7   1   0   5   3   6   9   8   2
     4           8   5   1   3   7   0   2   4   9   6
     5           0   3   5   9   6   8   4   1   2   7
     6           2   6   8   3   1   5   0   9   7   4
     7           2   3   4   6   7   5   9   8   1   0
     8           5   3   0   7   2   4   1   6   9   8
     9           9   2   6   1   0   3   7   5   4   8
    10           6   5   4   0   3   1   7   2   9   8
    11           2   4   5   6   3   1   9   7   0   8
    12           9   1   8   0   7   5   2   3   6   4
    13           4   9   6   2   0   1   7   8   3   5
    14           2   0   4   7   9   1   6   8   5   3
    15           9   7   3   8   6   1   0   5   4   2
    16           7   4   5   3   8   1   0   9   2   6
    17           6   8   4   0   2   7   3   5   1   9
    18           7   0   5   6   1   3   4   9   2   8
    19           9   8   1   5   2   7   0   4   3   6
    20           8   3   5   7   2   0   6   9   1   4
    21           3   7   2   6   5   8   1   9   0   4
    22           3   7   5   0   1   6   2   9   8   4
    23           2   3   9   5   7   8   6   4   1   0
    24           3   2   1   8   6   7   4   9   5   0
    25           1   8   9   5   2   3   6   0   4   7
    26           3   4   6   0   8   2   1   5   7   9
    27           4   7   5   3   6   1   2   8   9   0
    28           6   4   2   0   9   7   1   3   8   5
    29           2   6   1   4   5   9   7   3   8   0
```

D. RECIRCULATION LOGS D.

```
****************************************
*****        Data Generation       *****
*****  Mon Dec  4 14:03:44 1989    *****
****************************************

network type: 7

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: rec4.nni

binary: no                 bipolar: no
continuous: yes            training required: yes
randomize records: yes

random seed:      6317
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30
data set number       order of images in data set
     0              7   8   6   2   3   5   1   0   4   9
     1              5   7   3   0   6   4   8   9   2   1
     2              8   4   3   0   6   1   7   9   2   5
     3              1   9   8   0   3   5   4   2   7   6
     4              4   2   1   0   9   5   6   7   8   3
     5              2   5   6   8   0   7   9   1   4   3
     6              3   0   6   8   4   9   5   1   2   7
     7              0   7   1   8   4   2   6   9   3   5
     8              8   2   6   7   1   9   5   4   0   3
     9              6   1   5   9   0   2   8   4   3   7
    10              3   1   4   2   5   8   9   7   6   0
    11              1   8   7   6   2   5   0   9   4   3
    12              8   9   0   7   5   2   4   3   1   6
    13              1   9   7   6   5   4   3   2   0   8
    14              1   4   8   9   0   2   3   6   7   5
    15              8   6   9   1   0   7   3   2   4   5
    16              4   7   6   8   5   1   3   0   2   9
    17              0   2   7   3   8   9   6   4   5   1
    18              1   5   3   6   2   7   8   9   4   0
    19              6   4   5   3   8   7   0   2   9   1
    20              6   9   8   3   7   5   4   1   0   2
    21              4   3   8   5   1   2   6   0   9   7
    22              3   7   8   9   1   4   2   6   5   0
    23              4   3   5   7   2   0   9   1   8   6
    24              1   3   6   7   9   2   8   4   0   5
    25              9   3   4   8   2   5   1   0   7   6
    26              3   2   8   7   1   9   5   0   4   6
    27              0   3   9   7   1   5   6   4   8   2
    28              1   3   4   5   9   7   6   8   0   2
    29              0   6   4   3   1   9   8   2   7   5
```

```
*****************************************
*****        Data Generation        *****
*****   Mon Dec  4 14:05:38 1989    *****
*****************************************

network type: 7

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: rec5.nni

binary: no                bipolar: no
continuous: yes           training required: yes
randomize records: yes

random seed:      7371
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30
data set number      order of images in data set
      0             0    5    7    8    2    1    6    3    4    9
      1             3    2    9    7    8    0    4    5    1    6
      2             7    0    9    2    3    1    4    6    5    8
      3             9    8    2    7    6    1    0    5    3    4
      4             3    0    8    4    9    6    5    1    2    7
      5             6    1    7    2    3    4    8    9    5    0
      6             8    9    3    7    1    6    0    5    4    2
      7             5    4    7    0    1    3    9    8    2    6
      8             3    4    8    5    9    1    7    6    0    2
      9             1    5    3    8    0    6    9    7    4    2
     10             7    4    2    5    8    0    9    6    3    1
     11             2    9    6    0    3    4    1    5    8    7
     12             0    9    1    3    6    7    5    2    4    8
     13             7    2    3    5    9    0    6    8    1    4
     14             4    6    1    7    8    3    0    5    9    2
     15             6    3    7    2    0    1    9    5    8    4
     16             8    0    2    9    6    1    7    3    5    4
     17             4    9    5    8    3    0    2    6    1    7
     18             3    4    0    9    1    7    8    5    6    2
     19             2    3    4    9    1    8    7    0    6    5
     20             5    2    1    6    3    7    9    4    8    0
     21             6    2    5    7    8    1    0    4    9    3
     22             1    6    5    4    7    8    3    2    9    0
     23             7    5    2    3    8    0    4    1    9    6
     24             2    3    0    7    5    6    1    4    9    8
     25             1    3    8    6    5    2    4    9    0    7
     26             5    4    7    6    8    2    1    9    3    0
     27             8    2    0    4    7    1    9    3    5    6
     28             0    3    9    4    5    6    1    8    2    7
     29             5    8    9    4    2    0    6    3    7    1
```

D.4.2 Data Generation Logs (Testing Files)

```
****************************************
*****         Data Generation      *****
*****   Tue Dec  5 15:10:38 1989   *****
****************************************

network type: 7

input file: image
   images:   10   rows:     6   columns:    27   classes:    10
output file: recr1.nni

binary: no                  bipolar: no
continuous: yes             training required: yes
randomize records: yes

random seed:      8767
number of pixels to randomize in peaks: 3, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30
data set number          order of images in data set
     0              1   9   8   4   7   2   3   6   5   0
     1              8   6   1   3   5   4   0   7   9   2
     2              9   7   1   6   5   0   2   3   8   4
     3              9   3   7   4   6   2   8   5   1   0
     4              6   5   2   0   3   4   7   8   9   1
     5              3   7   9   0   1   2   4   5   6   8
     6              2   0   6   9   3   5   1   7   4   8
     7              5   4   0   1   6   8   3   7   2   9
     8              1   5   0   8   7   4   2   3   6   9
     9              0   4   9   8   5   2   3   7   1   6
    10              3   6   1   5   7   4   2   8   0   9
    11              7   6   8   0   9   1   2   5   4   3
    12              9   0   2   1   5   8   6   7   3   4
    13              2   0   1   4   3   6   5   9   8   7
    14              8   6   5   7   9   1   0   2   3   4
    15              0   2   8   4   1   7   9   6   5   3
    16              6   3   5   1   8   9   7   4   0   2
    17              4   7   5   9   8   1   2   6   0   3
    18              6   9   0   5   4   1   3   8   2   7
    19              5   3   6   2   9   8   0   4   7   1
    20              9   1   5   0   6   4   2   8   3   7
    21              7   0   6   4   5   1   8   3   9   2
    22              2   1   7   5   0   6   3   9   8   4
    23              2   7   0   8   6   5   9   1   4   3
    24              5   7   3   8   9   6   1   2   0   4
    25              6   2   1   8   5   9   0   7   4   3
    26              7   1   9   2   3   0   5   6   8   4
    27              8   0   3   5   1   4   7   9   6   2
    28              0   4   6   8   7   1   5   3   2   9
    29              5   9   4   7   2   3   6   0   1   8
```

D. RECIRCULATION LOGS D.

```
******************************************
*****        Data Generation        *****
*****   Tue Dec  5 15:12:58 1989    *****
******************************************

network type: 7

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: recr2.nni

binary: no                  bipolar: no
continuous: yes             training required: yes
randomize records: yes

random seed:      1737
number of pixels to randomize in peaks: 6, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30
data set number       order of images in data set
     0              6   1   4   8   3   5   7   0   2   9
     1              2   1   9   8   3   4   0   5   7   6
     2              0   9   6   7   5   2   8   4   1   3
     3              6   3   9   4   2   0   8   1   7   5
     4              3   5   9   2   0   4   8   6   1   7
     5              2   0   9   4   8   6   1   7   3   5
     6              4   8   3   5   9   2   7   1   6   0
     7              0   7   1   5   2   3   6   9   4   8
     8              0   7   4   6   5   8   2   3   1   9
     9              7   6   4   5   9   1   2   0   8   3
    10              0   8   6   1   7   4   9   5   3   2
    11              9   0   2   8   6   5   3   4   7   1
    12              4   8   7   9   2   5   3   0   1   6
    13              7   4   1   0   5   3   8   2   9   6
    14              1   4   2   0   9   3   5   8   7   6
    15              1   2   9   3   8   0   6   7   4   5
    16              4   6   5   8   9   0   7   3   1   2
    17              6   2   4   1   3   5   0   9   8   7
    18              6   4   0   8   7   5   9   1   2   3
    19              4   6   9   0   5   1   8   3   7   2
    20              4   3   8   5   2   0   6   7   1   9
    21              3   4   2   9   0   5   8   7   1   6
    22              3   0   7   4   5   8   2   1   9   6
    23              1   9   8   5   6   2   0   3   7   4
    24              2   7   8   1   9   0   4   3   5   6
    25              2   8   4   0   3   7   5   1   6   9
    26              4   0   3   9   7   6   5   8   1   2
    27              3   4   0   1   8   5   6   9   2   7
    28              6   7   3   0   5   2   8   9   1   4
    29              5   8   1   9   6   7   0   4   2   3
```

D. RECIRCULATION LOGS D.

```
*****************************************
*****        Data Generation        *****
*****   Tue Dec  5 15:15:42 1989    *****
*****************************************

network type: 7

input file: image
   images:    10   rows:      6   columns:     27   classes:     10
output file: recr3.nni

binary: no                  bipolar: no
continuous: yes             training required: yes
randomize records: yes

random seed:      2711
number of pixels to randomize in peaks: 9, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30
data set number        order of images in data set
      0             7   0   2   5   6   4   3   8   9   1
      1             1   7   6   4   9   3   2   8   5   0
      2             4   5   9   0   8   3   1   2   6   7
      3             7   4   8   6   1   9   3   2   5   0
      4             6   2   0   8   3   1   9   4   5   7
      5             6   8   5   2   1   0   4   7   3   9
      6             4   7   9   1   2   3   8   5   6   0
      7             8   2   3   5   7   6   4   1   9   0
      8             6   2   9   3   1   5   0   7   8   4
      9             5   4   9   3   2   6   8   1   7   0
     10             8   7   4   2   3   5   0   1   6   9
     11             0   9   2   7   1   8   6   5   3   4
     12             9   2   4   6   1   3   8   7   5   0
     13             5   9   3   1   0   8   7   2   4   6
     14             1   4   2   5   3   9   8   0   7   6
     15             8   3   5   9   7   4   2   1   6   0
     16             0   4   6   9   5   2   7   3   8   1
     17             8   2   5   1   4   7   3   9   6   0
     18             8   0   9   3   7   1   4   5   2   6
     19             1   0   5   6   8   4   9   2   7   3
     20             4   8   5   6   2   3   0   1   9   7
     21             2   0   8   6   4   9   5   3   1   7
     22             7   3   9   5   6   0   8   1   2   4
     23             0   8   9   5   2   7   3   6   1   4
     24             1   4   5   2   7   0   8   6   3   9
     25             2   4   8   9   7   3   0   6   5   1
     26             1   8   3   7   0   9   4   6   5   2
     27             9   1   5   6   7   0   3   4   8   2
     28             4   1   3   6   0   5   2   8   7   9
     29             2   3   0   9   7   6   4   1   5   8
```

D. RECIRCULATION LOGS D.

```
****************************************
*****         Data Generation      *****
*****    Tue Dec  5 15:18:04 1989  *****
****************************************

network type: 7

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: recr4.nni

binary: no                bipolar: no
continuous: yes           training required: yes
randomize records: yes

random seed:     5929
number of pixels to randomize in peaks: 12, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30
data set number       order of images in data set
     0           7   1   5   4   8   6   9   2   3   0
     1           1   6   0   5   3   8   9   4   2   7
     2           9   3   5   1   0   4   7   6   2   8
     3           5   1   3   2   8   9   7   6   0   4
     4           3   5   1   0   4   2   6   9   8   7
     5           3   8   7   4   2   9   5   1   0   6
     6           9   7   5   0   2   3   8   6   4   1
     7           1   5   3   8   4   0   7   9   6   2
     8           5   4   6   8   7   2   3   1   9   0
     9           8   0   4   1   7   3   2   6   9   5
    10           7   8   2   6   4   5   1   9   0   3
    11           9   7   4   1   0   5   2   8   3   6
    12           5   9   2   7   1   3   0   6   8   4
    13           7   9   8   6   0   2   1   5   4   3
    14           0   9   5   1   8   7   3   2   6   4
    15           5   8   3   2   7   0   1   9   4   6
    16           6   5   1   2   0   4   7   3   8   9
    17           7   4   9   0   5   1   3   6   2   8
    18           3   6   9   8   1   2   7   0   4   5
    19           2   7   4   1   0   9   5   3   8   6
    20           3   7   2   6   8   5   4   0   1   9
    21           1   2   3   0   5   7   6   4   9   8
    22           9   0   2   8   7   3   6   1   4   5
    23           2   5   3   4   6   1   0   9   8   7
    24           5   8   4   1   9   6   3   2   7   0
    25           3   4   8   9   2   5   6   1   0   7
    26           8   5   9   4   1   3   6   7   0   2
    27           3   2   5   4   0   9   1   6   7   8
    28           2   7   9   8   4   1   3   5   6   0
    29           8   0   6   2   9   1   5   3   4   7
```

D. RECIRCULATION LOGS D.

D.4.3 Test Results Logs

(a) Results after 302, 603 and 904 Learning Trials

```
*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 14:31:36 1989   *****
*****************************************

network type: 7

expected values file: rec1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Detailed error reporting disabled

number correct: 120, total input: 300, per cent correct: 40.0

*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 14:33:32 1989   *****
*****************************************

network type: 7

expected values file: rec1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed error reporting disabled

number correct: 60, total input: 300, per cent correct: 20.0

*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 14:45:08 1989   *****
*****************************************

network type: 7

expected values file: rec2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Detailed error reporting disabled

number correct: 210, total input: 300, per cent correct: 70.0

*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 14:47:04 1989   *****
*****************************************

network type: 7

expected values file: rec2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed error reporting disabled

number correct: 60, total input: 300, per cent correct: 20.0
```

D. RECIRCULATION LOGS D.

```
*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 15:00:00 1989   *****
*****************************************

network type: 7

expected values file: rec3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Detailed error reporting disabled

number correct: 210, total input: 300, per cent correct: 70.0

*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 15:01:56 1989   *****
*****************************************

network type: 7

expected values file: rec3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed error reporting disabled

number correct: 90, total input: 300, per cent correct: 30.0
```

(b) Results after 1205, 1506 and 1807 Learning Trials

```
*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 15:11:20 1989   *****
*****************************************

network type: 7

expected values file: rec4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image
       6            4, 19, 29, 38, 42, 51, 69, 76, 82, 96,104
       6          115,126,138,146,158,169,172,185,198,210,216
       6          227,235,246,255,262,280,290,298

number correct: 270, total input: 300, per cent correct: 90.0

*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 15:13:24 1989   *****
*****************************************

network type: 7

expected values file: rec4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000
```

```
Detailed error reporting disabled

number correct: 180, total input: 300, per cent correct: 60.0

****************************************
*****       Data Comparison       *****
*****   Mon Dec  4 15:27:32 1989   *****
****************************************

network type: 7

expected values file: rec5.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image
      6             5, 12, 24, 33, 49, 54, 70, 79, 90,100,103
      6           111,128,132,150,154,163,177,190,191,202,212
      6           228,233,241,256,266,272,289,295

number correct: 270, total input: 300, per cent correct: 90.0

****************************************
*****       Data Comparison       *****
*****   Mon Dec  4 15:29:24 1989   *****
****************************************

network type: 7

expected values file: rec5.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed error reporting disabled

number correct: 210, total input: 300, per cent correct: 70.0

****************************************
*****       Data Comparison       *****
*****   Mon Dec  4 15:39:30 1989   *****
****************************************

network type: 7

expected values file: rec1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image
      6             2, 15, 28, 37, 41, 56, 70, 80, 84, 94,108
      6           120,122,137,150,159,169,178,187,199,203,215
      6           221,235,249,254,261,278,287,300

number correct: 270, total input: 300, per cent correct: 90.0

****************************************
*****       Data Comparison       *****
*****   Mon Dec  4 15:41:24 1989   *****
****************************************

network type: 7

expected values file: rec1.nni
```

```
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image
       6            2, 15, 28, 37, 41, 56, 70, 80, 84, 94,108
       6          120,122,137,150,159,169,178,187,199,203,215
       6          221,235,249,254,261,278,287,300

number correct: 270, total input: 300, per cent correct: 90.0
```

(c) Results after 2108, 2409 and 2710 Learning Trials

```
****************************************
*****       Data Comparison       *****
*****   Mon Dec  4 15:52:24 1989  *****
****************************************

network type: 7

expected values file: rec3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image
       1            7, 12, 29, 40, 47, 59, 61, 71, 85, 92,108
       1          111,127,134,141,160,169,175,189,195,205,213
       1          227,231,242,255,266,277,283,291

number correct: 270, total input: 300, per cent correct: 90.0

****************************************
*****       Data Comparison       *****
*****   Mon Dec  4 15:54:28 1989  *****
****************************************

network type: 7

expected values file: rec3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image
       6            7, 12, 29, 40, 47, 59, 61, 71, 85, 92,108
       6          111,127,134,141,160,169,175,189,195,205,213
       6          227,231,242,255,266,277,283,291

number correct: 270, total input: 300, per cent correct: 90.0

****************************************
*****       Data Comparison       *****
*****   Mon Dec  4 16:05:06 1989  *****
****************************************

network type: 7

expected values file: rec2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

number correct: 300, total input: 300, per cent correct: 100.0
```

```
*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 16:07:02 1989   *****
*****************************************

network type: 7

expected values file: rec2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image
      6             3, 13, 21, 34, 49, 53, 68, 72, 86,100,106
      6           116,126,140,142,151,170,177,190,198,208,213
      6           222,231,250,253,265,273,290,299

number correct: 270, total input: 300, per cent correct: 90.0

*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 16:15:50 1989   *****
*****************************************

network type: 7

expected values file: rec1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

number correct: 300, total input: 300, per cent correct: 100.0

*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 16:17:44 1989   *****
*****************************************

network type: 7

expected values file: rec1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image
      1             2, 15, 28, 37, 41, 56, 70, 80, 84, 94,108
      1           120,122,137,150,159,169,178,187,199,203,215
      1           221,235,249,254,261,278,287,300

number correct: 270, total input: 300, per cent correct: 90.0
```

(d) Results after 3011 Learning Trials

```
*****************************************
*****        Data Comparison       *****
*****   Mon Dec  4 16:27:12 1989   *****
*****************************************

network type: 7

expected values file: rec3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000
```

D. RECIRCULATION LOGS D.

```
number correct: 300, total input: 300, per cent correct: 100.0

******************************************
*****        Data Comparison        *****
*****    Mon Dec  4 16:28:52 1989   *****
******************************************

network type: 7

expected values file: rec3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

number correct: 300, total input: 300, per cent correct: 100.0

******************************************
*****        Data Comparison        *****
*****    Tue Dec  5 15:53:36 1989   *****
******************************************

network type: 7

expected values file: recr1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image
       2           69
       6           86,198

number correct: 297, total input: 300, per cent correct: 99.0

******************************************
*****        Data Comparison        *****
*****    Tue Dec  5 15:56:06 1989   *****
******************************************

network type: 7

expected values file: recr1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

       1            2
       6           16
       3           18, 43
       6           46, 49, 56, 69, 74, 77
       1           78
       6           86, 92,102,105
       3          131
       1          134
       6          148,170,175
       4          194
       6          198
       2          209
       4          214
       6          226
       3          244
       1          247
       6          285
```

```
      2          292
      4          295

number correct: 270, total input: 300, per cent correct: 90.0

****************************************
*****        Data Comparison      *****
*****   Tue Dec  5 16:02:12 1989  *****
****************************************

network type: 7

expected values file: recr2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image
      6             3, 14, 28
      5            47, 75
      3           159
      6           261
      3           274
      1           298

number correct: 291, total input: 300, per cent correct: 97.0

****************************************
*****        Data Comparison      *****
*****   Tue Dec  5 16:04:34 1989  *****
****************************************

network type: 7

expected values file: recr2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed error reporting disabled

number correct: 226, total input: 300, per cent correct: 75.3

****************************************
*****        Data Comparison      *****
*****   Tue Dec  5 16:18:34 1989  *****
****************************************

network type: 7

expected values file: recr3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image
      6             4,  8, 10, 27, 38, 48, 77
      1            78
      5            92
      6            99,101,112,120,147
      5           151
      4           154
      1           157
      6           162
      3           170
      5           179
```

```
        1          187
        6          196,198,211,227,229
        5          237
        2          238
        6          253,260,272
        1          281
        6          285
        3          287
        4          290

number correct: 265, total input: 300, per cent correct: 88.3

****************************************
*****        Data Comparison      *****
*****   Tue Dec  5 16:21:42 1989  *****
****************************************

network type: 7

expected values file: recr3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed error reporting disabled

number correct: 187, total input: 300, per cent correct: 62.3

****************************************
*****        Data Comparison      *****
*****   Tue Dec  5 16:28:16 1989  *****
****************************************

network type: 7

expected values file: recr4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

        6           8, 20, 29, 33
        5          51
        1          52
        5          56
        6          72, 80, 89
       12          96
        6          101,103,106
        3          112
        2          115,119
        5          123
        2          128
        6          139
        2          146,150
        4          157
        1          161
        6          162
        5          164
        6          167,172
        1          176
        6          177,178,180,205,207,212
        5          224
        6          234,238
        2          243
        6          255,263,272
        3          274
```

```
     6        277,282
     4        287

number correct: 254, total input: 300, per cent correct: 84.7

****************************************
*****        Data Comparison       *****
*****   Tue Dec  5 16:30:28 1989   *****
****************************************

network type: 7

expected values file: recr4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed error reporting disabled

number correct: 173, total input: 300, per cent correct: 57.7
```

(e) Results after 3914 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Wed Dec  6 15:29:22 1989   *****
****************************************

network type: 7

expected values file: rec4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000


number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****        Data Comparison       *****
*****   Wed Dec  6 15:36:26 1989   *****
****************************************

network type: 7

expected values file: recr1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

     6        86,198
number correct: 298, total input: 300, per cent correct: 99.3

****************************************
*****        Data Comparison       *****
*****   Wed Dec  6 15:38:48 1989   *****
****************************************

network type: 7

expected values file: recr1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000
```

D. RECIRCULATION LOGS D.

```
Number of Errors  Record Number
  per Image

      5        16
      2        18
      6        46
      3        56
      6        69
      5        74
      6        77
      2        78
      6        86, 92,102,105
      2       134
      5       148
      6       175,198
      4       214
      2       215
     11       226
      6       285
      2       292
number correct: 279, total input: 300, per cent correct: 93.0

****************************************
*****         Data Comparison      *****
*****   Wed Dec  6 15:45:12 1989   *****
****************************************

network type: 7

expected values file: recr2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

      6         3
      4        14
      6        28
      2        47
      3        75,159
      2       247
      6       261
      4       274
      3       298
number correct: 290, total input: 300, per cent correct: 96.7

****************************************
*****         Data Comparison      *****
*****   Wed Dec  6 15:47:34 1989   *****
****************************************

network type: 7

expected values file: recr2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 230, total input: 300, per cent correct: 76.7

****************************************
*****         Data Comparison      *****
*****   Wed Dec  6 15:53:38 1989   *****
****************************************
```

```
         3        80
         6        89
        12        96
         6       101,103,106,112,115
         2       126
         5       128
         3       131
         6       139
         2       146
         6       150,162
         4       164
         6       167,172,177,178,180,205,207
         3       212
         2       224
         6       234,238
         3       240
         2       243
         6       255,263,272
         3       273
         4       274
         6       277,282
         4       287
         1       289
number correct: 255, total input: 300, per cent correct: 85.0

****************************************
*****         Data Comparison      *****
*****    Wed Dec  6 16:04:34 1989  *****
****************************************

network type: 7

expected values file: recr4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 179, total input: 300, per cent correct: 59.7
```

(f) Results after 4817 Learning Trials

```
****************************************
*****         Data Comparison      *****
*****    Thu Dec  7 10:35:56 1989  *****
****************************************

network type: 7

expected values file: rec1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000


number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****         Data Comparison      *****
*****    Thu Dec  7 10:42:06 1989  *****
****************************************

network type: 7

expected values file: recr1.nni
actual values file: recirc.nno
```

```
error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       1        46
       6        86,198
number correct: 297, total input: 300, per cent correct: 99.0

****************************************
*****        Data Comparison      *****
*****   Thu Dec  7 10:44:10 1989  *****
****************************************

network type: 7

expected values file: recr1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

       1         2
       6        16, 46, 69
       5        77
       1        78
       6        86, 92,102,105,134
       1       140
       3       148
       6       175,198
       4       214
       2       215
      12       226
       6       285
       2       292
number correct: 280, total input: 300, per cent correct: 93.3

****************************************
*****        Data Comparison      *****
*****   Thu Dec  7 10:49:58 1989  *****
****************************************

network type: 7

expected values file: recr2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       6         3, 14, 28
       5        47
       1        75
       5       159,247
       6       261
       5       274
       1       290
       6       298
number correct: 289, total input: 300, per cent correct: 96.3

****************************************
*****        Data Comparison      *****
*****   Thu Dec  7 10:52:02 1989  *****
****************************************
```

D. RECIRCULATION LOGS D.

```
network type: 7

expected values file: recr2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 231, total input: 300, per cent correct: 77.0

****************************************
*****        Data Comparison      *****
*****   Thu Dec  7 10:57:36 1989   *****
****************************************

network type: 7

expected values file: recr3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       6          4,  8,  9, 10, 27, 38, 48, 77, 92, 99101
       6        112,120,147,151,154
       2        157
       6        162
       5        179,187
       6        190,196,198
       1        201,211
       6        227,229
       2        237
       6        238,253
       4        255,260
       5        272
       1        279,281
       6        285,290
number correct: 263, total input: 300, per cent correct: 87.7

****************************************
*****        Data Comparison      *****
*****   Thu Dec  7 10:59:46 1989   *****
****************************************

network type: 7

expected values file: recr3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 194, total input: 300, per cent correct: 64.7

****************************************
*****        Data Comparison      *****
*****   Thu Dec  7 11:07:46 1989   *****
****************************************

network type: 7

expected values file: recr4.nni
actual values file: recirc.nno
```

```
error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

      6        8
      2        16
      5        20
      6        29
      5        33, 51
      6        56
      1        69
      6        72
      3        80
      6        89
     12        96
      6        101,103,106,112
     11        115
      5        126
      7        128
      6        131,139
      3        146
      6        150,162
      2        164
      6        167,172,177,178
      2        180
      4        188
      1        189
      6        205,207
      4        212
      6        234,238
      5        240
      2        243
      1        252
      6        255
      3        261
      6        263,272
      4        273
      6        274
      1        277
      6        282
      1        284
      3        287
      1        289
number correct: 249, total input: 300, per cent correct: 83.0

****************************************
*****         Data Comparison      *****
*****    Thu Dec  7 11:09:50 1989  *****
****************************************

network type: 7

expected values file: recr4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 174, total input: 300, per cent correct: 58.0
```

(g) Results after 6021 Learning Trials

```
****************************************
*****         Data Comparison      *****
*****    Thu Dec  7 11:35:16 1989  *****
```

D. RECIRCULATION LOGS D.

```
****************************************

network type: 7

expected values file: rec4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000


number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****        Data Comparison        *****
*****    Thu Dec  7 11:40:50 1989   *****
****************************************

network type: 7

expected values file: recr1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       1          46
       6          86,198
       5         226
number correct: 296, total input: 300, per cent correct: 98.7

****************************************
*****        Data Comparison        *****
*****    Thu Dec  7 11:43:06 1989   *****
****************************************

network type: 7

expected values file: recr1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

       6           2, 16, 46, 69
       1          77
       2          78
       6          86, 92
       3         100
       6         102,105,134
       2         140
       6         175,198,214
       1         215
      12         226
       4         239
       6         285
       2         292
number correct: 279, total input: 300, per cent correct: 93.0

****************************************
*****        Data Comparison        *****
*****    Thu Dec  7 11:48:58 1989   *****
****************************************

network type: 7
```

```
expected values file: recr2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       6          3, 14, 28
       5         47,131
       6        159,247
       1        249
       6        261,274
       5        290
       6        298
number correct: 288, total input: 300, per cent correct: 96.0

****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 11:51:02 1989   *****
****************************************

network type: 7

expected values file: recr2.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 227, total input: 300, per cent correct: 75.7

****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 11:56:48 1989   *****
****************************************

network type: 7

expected values file: recr3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       6          4
       5          8
       6          9, 10, 27, 38, 48, 77, 92
       1         96
       6         99,101,112,120,147,151,154
       1        155
       4        157
       6        162,179,187,190,196,198
       3        201
       4        204
       1        211,225
       6        227,229,238,253
       5        255
       4        260
       2        279,281
       8        285
       6        290
number correct: 261, total input: 300, per cent correct: 87.0
```

```
****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 11:58:50 1989   *****
****************************************

network type: 7

expected values file: recr3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 192, total input: 300, per cent correct: 64.0

****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 12:05:34 1989   *****
****************************************

network type: 7

expected values file: recr4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       6         8
       4        16
       5        20
       6        29
       3        33, 51
       6        56
       3        57
       1        69
       6        72, 89
      12        96
       6        101,103,106,112
      12        115
       5        126
       7        128
       6        131,139
       4        146
       6        150,162
       1        164
       6        167,172
       5        177
       6        178,188
       2        189
       3        200
       6        205,207
       4        212
       6        234,238,240
       4        243
       3        252
       6        255,261,263
       1        267
       6        272,273,274,282
       1        284,287
       4        289
number correct: 249, total input: 300, per cent correct: 83.0

****************************************
*****        Data Comparison       *****
```

```
*****   Thu Dec  7 12:47:34 1989   *****
*****************************************

network type: 7

expected values file: recr4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 164, total input: 300, per cent correct: 54.7
```

(h) Results after 7526 Learning Trials

```
*****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 13:17:14 1989   *****
*****************************************

network type: 7

expected values file: rec5.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000


number correct: 300, total input: 300, per cent correct: 100.0

*****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 13:22:54 1989   *****
*****************************************

network type: 7

expected values file: recr1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       5        46
       6        86
       2        134
       6        198,226
number correct: 295, total input: 300, per cent correct: 98.3

*****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 13:25:10 1989   *****
*****************************************

network type: 7

expected values file: recr1.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

       6        2, 16, 46, 69
```

```
      2        78
      6        86, 92,100,102,105,134
      2       138
      4       140
      6       175,198,214,224
     12       226
      6       239,285
number correct: 280, total input: 300, per cent correct: 93.3

*****************************************
*****          Data Comparison      *****
*****   Thu Dec  7 13:31:16 1989    *****
*****************************************

network type: 7

expected values file: recr2.mni
actual values file: recirc.mno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

      6          3, 14, 28, 47
      1       101
      6       131,159
      1       182
      6       247
      2       249
      6       261,274,290,298
number correct: 286, total input: 300, per cent correct: 95.3

*****************************************
*****          Data Comparison      *****
*****   Thu Dec  7 13:33:30 1989    *****
*****************************************

network type: 7

expected values file: recr2.mni
actual values file: recirc.mno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

      6          3,  7, 14
     12        19
      8        21
      5        22
      6        23
      3        24
      6        28, 31, 34
      2        35
      6        37
     12        47, 50
      2        57
      3        58
      1        61
      5        62
      6        64, 66
     11        67
      6        75
      5        85
      6        87, 92
     12       101
```

```
       6       103
       8       105
       1       108
       3       116
       1       123
      12       131
       6       133,139,150,151,159
       5       162,164,166
       7       169
       9       171
       5       172
       3       173
       6       182
       3       185
       6       193,195,201,212
       5       213
       2       220
       6       223,224
       4       237
       6       239
      11       242
       6       247,249
       2       252
       6       256,261
       9       262
       1       264
       9       268
       6       273
      12       274
       6       277
       5       279
       2       280
       6       282
      11       287
      12       288
       6       290,298
number correct: 224, total input: 300, per cent correct: 74.7

****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 13:39:46 1989   *****
****************************************

network type: 7

expected values file: recr3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       6         4
       1         8
       6         9, 10
       1        21
       5        27
       6        38, 48, 77, 92
       4        96
       6        99,101,112,120,147,151,154
       3       155
       6       157,162,179,187,190,196,198
       5       201
       6       204
       3       225
       6       227,229
       3       230
```

```
        6       238,253,255
        3       279
        2       281
        9       285
        6       290
number correct: 261, total input: 300, per cent correct: 87.0

****************************************
*****       Data Comparison        *****
*****   Thu Dec  7 13:42:04 1989   *****
****************************************

network type: 7

expected values file: recr3.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

        6         1,  4,  6,  8,  9, 10
       12        19
        6        21, 24
        1        25
       10        27
        1        28
        6        29
        1        30
       12        31
        6        34, 37, 38, 39
        5        46
        2        47
        6        48, 49
        1        52
        9        53
        2        58, 60
        5        63
        1        68
        6        69, 74
        5        75
        4        76
        6        77
        2        78
        6        79
        1        89
        6        92, 93, 96, 99,101,102,106
        5       109
        6       112
        2       113
        6       120,121
        3       123
        6       128,129
        2       137
        6       139,143
        1       146
       12       147
        6       151,154
       12       155
        6       157,162
        9       163
        2       164
        5       165
        4       166
        6       170,175
        4       178
       12       179
```

```
      2        183
      6        187,190,194,196,198,199
      3        200
      6        201
     12        204
      6        211
      2        212,215
      1        216
      6        225
     12        227
      6        229,230
      1        233
      6        237,238,242,248
      3        249
      6        250
     12        253,255
      6        259,260
      2        264
      1        271
      6        272
      9        276
      6        278,279
      5        280
      6        281
     12        285
      7        286
      6        287
     10        289
     12        290
      6        291
      7        294
      6        296
      5        297
number correct: 184, total input: 300, per cent correct: 61.3

****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 13:48:04 1989   *****
****************************************

network type: 7

expected values file: recr4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       3          1
       1          5
       6          8
       5          16, 20
       6         29
       1         33
       4         36
       2         37
       3         51
       6         56
       5         57
       1         69
       6         72
       2         77
       6         89
      12         96
       6        101,103
       2        105
      6        106,112
     12        115
      5        126
      7        128
      6        131,139,146,150,162
      1        164
      6        167,172,178,188
      3        189
      6        200,205,207,212,234,238,240
      4        243
      5        252
      6        255
     10        261
      6        263
      1        267
      6        272,273,274,282
      1        284,288
      5        289
number correct: 244, total input: 300, per cent correct: 81.3

****************************************
*****       Data Comparison        *****
*****   Thu Dec  7 13:50:38 1989   *****
****************************************

network type: 7

expected values file: recr4.nni
actual values file: recirc.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

     12          1
      9          2
      4          4
      6          5,  6
      7          7
      6          8
     10         12
      6         13
     11         16
      3         18
      7         19
     18         20
      3         21
      1         23
      6         24
      1         27
      5         28
      6         29, 33, 36, 37
      3         38
      2         40
      6         42, 48
      1         50
      6         51, 52, 55
      7         56
     12         57
      5         62
      6         63
      1         65
      6         68
      5         69
      2         71
      6         72
      8         73
```

```
 1      75
12      77
 3      80, 84
 4      87
 6      89
 1      91
12      96
 6      100
10      101
 6      103
 2      104
 6      105,106
12      112
 2      113
12      115
 6      117
 7      119
 6      121
12      122
 6      123
 1      124
 6      126
12      128
 6      130
12      131
 2      134
 6      137,139
 3      140
 1      143
 6      146
 2      147
 6      150,154
 9      155
 5      157
16      161
12      162,164
 6      166
12      167
 6      168,171,172,176,177
 8      178
 6      179,180
 7      182
 3      184
 2      185
12      188
 6      189
 9      190
 6      200,201
 1      202
 6      205,206,207,210,212,217
 5      220
 2      223
 4      226
 6      229,234,235
12      238
 6      240,243
 1      245
 6      246,249,252
 4      253
 6      254,255,260
12      261
10      263
 6      267
 8      268,272
 6      273,274
 1      275
 6      277,278,279
12      282
```

```
        6       284,286,287,288
       12       289
        6       293
        4       294
        2       299
        5       300
number correct: 156, total input: 300, per cent correct: 52.0
```

D.5 Back Propagation Network

D.5.1 Data Generation Logs (Training Files)

```
*****************************************
*****         Data Generation       *****
*****   Thu Dec  7 14:39:56 1989    *****
*****************************************

network type: 6

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bp1.nni

binary: no                  bipolar: no
continuous: yes             training required: yes
randomize records: yes

random seed:      9910
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number      order of images in data set

       0             0   2   1   5   7   9   6   3   8   4
       1             6   5   0   7   2   8   3   9   1   4
       2             5   9   7   4   3   6   1   2   0   8
       3             9   1   3   7   0   8   2   5   4   6
       4             2   4   1   5   7   9   6   0   8   3
       5             4   8   0   9   3   2   7   6   5   1
       6             9   8   7   3   5   0   4   6   1   2
       7             8   7   1   0   3   5   9   6   4   2
       8             5   7   1   2   4   8   3   0   6   9
       9             1   0   9   2   6   7   5   8   3   4
      10             6   1   9   3   8   4   0   2   7   5
      11             9   5   4   8   1   0   3   6   7   2
      12             4   2   0   3   1   8   9   5   7   6
      13             7   0   5   9   3   6   2   1   8   4
      14             6   5   0   4   7   9   8   3   1   2
      15             5   0   1   4   8   7   9   6   2   3
      16             6   8   4   5   0   3   7   1   2   9
      17             7   3   5   8   6   9   4   2   0   1
      18             3   8   4   5   6   1   2   9   0   7
      19             6   1   4   5   8   9   0   7   2   3
      20             3   4   2   5   8   6   7   0   9   1
      21             6   0   1   4   2   5   7   9   8   3
      22             2   9   7   4   1   8   3   0   5   6
      23             6   9   5   8   2   7   0   4   3   1
      24             1   3   8   4   7   0   9   6   2   5
      25             4   1   7   2   5   6   0   8   3   9
      26             2   5   4   9   8   3   1   6   7   0
      27             1   0   8   9   3   6   4   2   5   7
      28             3   9   7   6   0   8   2   4   1   5
      29             9   8   7   4   0   3   5   1   6   2
```

```
*****************************************
*****       Data Generation        *****
*****   Thu Dec  7 14:41:48 1989   *****
*****************************************

network type: 6

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bp2.nni

binary: no               bipolar: no
continuous: yes          training required: yes
randomize records: yes

random seed:      1576
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number      order of images in data set

      0              4   7   2   9   8   3   6   0   1   5
      1              1   9   2   3   0   5   4   7   8   6
      2              2   0   3   4   9   1   5   8   7   6
      3              8   0   3   2   4   9   7   6   5   1
      4              7   5   4   8   1   3   6   0   2   9
      5              8   9   2   7   5   1   0   3   4   6
      6              8   3   4   6   9   1   5   2   7   0
      7              1   2   5   6   0   8   3   9   4   7
      8              9   3   4   8   5   2   1   0   7   6
      9              3   7   9   1   0   8   5   6   4   2
     10              8   6   5   1   7   2   0   9   3   4
     11              4   9   6   8   0   2   3   7   1   5
     12              4   8   5   6   7   2   0   3   9   1
     13              0   4   7   8   9   6   1   3   5   2
     14              9   2   6   4   0   3   8   7   5   1
     15              2   4   3   5   6   8   7   0   9   1
     16              5   1   7   3   4   8   9   6   0   2
     17              5   7   9   0   3   1   2   6   4   8
     18              8   0   3   4   7   9   6   5   1   2
     19              6   8   0   7   3   4   5   2   9   1
     20              5   4   8   9   3   1   7   2   6   0
     21              9   3   2   6   1   7   5   0   4   8
     22              9   2   4   8   1   6   3   5   0   7
     23              2   1   8   9   0   4   7   6   3   5
     24              9   4   8   3   6   7   1   0   5   2
     25              3   8   2   1   5   7   6   4   0   9
     26              9   6   3   0   2   4   8   5   7   1
     27              8   4   2   6   3   1   5   0   9   7
     28              7   5   3   6   0   4   8   1   9   2
     29              8   6   4   9   7   1   0   5   2   3
```

D. BACK PROPAGATION LOGS D.

```
******************************************
*****        Data Generation        *****
*****    Thu Dec  7 14:45:48 1989    *****
******************************************

network type: 6

input file: image
   images:     10   rows:      6   columns:     27   classes:     10
output file: bp3.nni

binary: no                  bipolar: no
continuous: yes             training required: yes
randomize records: yes

random seed:      4589
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number      order of images in data set

      0              4    7    6    8    0    3    2    1    9    5
      1              4    2    9    5    0    8    6    7    1    3
      2              7    0    4    1    8    3    9    5    2    6
      3              4    7    1    0    5    3    6    9    8    2
      4              8    5    1    3    7    0    2    4    9    6
      5              0    3    5    9    6    8    4    1    2    7
      6              2    6    8    3    1    5    0    9    7    4
      7              2    3    4    6    7    5    9    8    1    0
      8              5    3    0    7    2    4    1    6    9    8
      9              9    2    6    1    0    3    7    5    4    8
     10              6    5    4    0    3    1    7    2    9    8
     11              2    4    5    6    3    1    9    7    0    8
     12              9    1    8    0    7    5    2    3    6    4
     13              4    9    6    2    0    1    7    8    3    5
     14              2    0    4    7    9    1    6    8    5    3
     15              9    7    3    8    6    1    0    5    4    2
     16              7    4    5    3    8    1    0    9    2    6
     17              6    8    4    0    2    7    3    5    1    9
     18              7    0    5    6    1    3    4    9    2    8
     19              9    8    1    5    2    7    0    4    3    6
     20              8    3    5    7    2    0    6    9    1    4
     21              3    7    2    6    5    8    1    9    0    4
     22              3    7    5    0    1    6    2    9    8    4
     23              2    3    9    5    7    8    6    4    1    0
     24              3    2    1    8    6    7    4    9    5    0
     25              1    8    9    5    2    3    6    0    4    7
     26              3    4    6    0    8    2    1    5    7    9
     27              4    7    5    3    6    1    2    8    9    0
     28              6    4    2    0    9    7    1    3    8    5
     29              2    6    1    4    5    9    7    3    8    0
```

```
*****************************************
*****        Data Generation       *****
*****   Thu Dec  7 14:47:32 1989   *****
*****************************************

network type: 6

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bp4.nni

binary: no                bipolar: no
continuous: yes           training required: yes
randomize records: yes

random seed:     6317
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number      order of images in data set

       0            7   8   6   2   3   5   1   0   4   9
       1            5   7   3   0   6   4   8   9   2   1
       2            8   4   3   0   6   1   7   9   2   5
       3            1   9   8   0   3   5   4   2   7   6
       4            4   2   1   0   9   5   6   7   8   3
       5            2   5   6   8   0   7   9   1   4   3
       6            3   0   6   8   4   9   5   1   2   7
       7            0   7   1   8   4   2   6   9   3   5
       8            8   2   6   7   1   9   5   4   0   3
       9            6   1   5   9   0   2   8   4   3   7
      10            3   1   4   2   5   8   9   7   6   0
      11            1   8   7   6   2   5   0   9   4   3
      12            8   9   0   7   5   2   4   3   1   6
      13            1   9   7   6   5   4   3   2   0   8
      14            1   4   8   9   0   2   3   6   7   5
      15            8   6   9   1   0   7   3   2   4   5
      16            4   7   6   8   5   1   3   0   2   9
      17            0   2   7   3   8   9   6   4   5   1
      18            1   5   3   6   2   7   8   9   4   0
      19            6   4   5   3   8   7   0   2   9   1
      20            6   9   8   3   7   5   4   1   0   2
      21            4   3   8   5   1   2   6   0   9   7
      22            3   7   8   9   1   4   2   6   5   0
      23            4   3   5   7   2   0   9   1   8   6
      24            1   3   6   7   9   2   8   4   0   5
      25            9   3   4   8   2   5   1   0   7   6
      26            3   2   8   7   1   9   5   0   4   6
      27            0   3   9   7   1   5   6   4   8   2
      28            1   3   4   5   9   7   6   8   0   2
      29            0   6   4   3   1   9   8   2   7   5
```

D. BACK PROPAGATION LOGS D.

```
*****************************************
*****        Data Generation       *****
*****   Thu Dec  7 14:48:54 1989   *****
*****************************************

network type: 6

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bp5.nni

binary: no                 bipolar: no
continuous: yes            training required: yes
randomize records: yes

random seed:      7371
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number      order of images in data set

      0              0   5   7   8   2   1   6   3   4   9
      1              3   2   9   7   8   0   4   5   1   6
      2              7   0   9   2   3   1   4   6   5   8
      3              9   8   2   7   6   1   0   5   3   4
      4              3   0   8   4   9   6   5   1   2   7
      5              6   1   7   2   3   4   8   9   5   0
      6              8   9   3   7   1   6   0   5   4   2
      7              5   4   7   0   1   3   9   8   2   6
      8              3   4   8   5   9   1   7   6   0   2
      9              1   5   3   8   0   6   9   7   4   2
     10              7   4   2   5   8   0   9   6   3   1
     11              2   9   6   0   3   4   1   5   8   7
     12              0   9   1   3   6   7   5   2   4   8
     13              7   2   3   5   9   0   6   8   1   4
     14              4   6   1   7   8   3   0   5   9   2
     15              6   3   7   2   0   1   9   5   8   4
     16              8   0   2   9   6   1   7   3   5   4
     17              4   9   5   8   3   0   2   6   1   7
     18              3   4   0   9   1   7   8   5   6   2
     19              2   3   4   9   1   8   7   0   6   5
     20              5   2   1   6   3   7   9   4   8   0
     21              6   2   5   7   8   1   0   4   9   3
     22              1   6   5   4   7   8   3   2   9   0
     23              7   5   2   3   8   0   4   1   9   6
     24              2   3   0   7   5   6   1   4   9   8
     25              1   3   8   6   5   2   4   9   0   7
     26              5   4   7   6   8   2   1   9   3   0
     27              8   2   0   4   7   1   9   3   5   6
     28              0   3   9   4   5   6   1   8   2   7
     29              5   8   9   4   2   0   6   3   7   1
```

D.5.2 Data Generation Logs (Testing Files)

```
*****************************************
*****       Data Generation        *****
*****   Thu Dec  7 14:50:44 1989   *****
*****************************************

network type: 6

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bpr1.nni

binary: no                bipolar: no
continuous: yes           training required: yes
randomize records: yes

random seed:     8767
number of pixels to randomize in peaks: 3, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number      order of images in data set

      0             1   9   8   4   7   2   3   6   5   0
      1             8   6   1   3   5   4   0   7   9   2
      2             9   7   1   6   5   0   2   3   8   4
      3             9   3   7   4   6   2   8   5   1   0
      4             6   5   2   0   3   4   7   8   9   1
      5             3   7   9   0   1   2   4   5   6   8
      6             2   0   6   9   3   5   1   7   4   8
      7             5   4   0   1   6   8   3   7   2   9
      8             1   5   0   8   7   4   2   3   6   9
      9             0   4   9   8   5   2   3   7   1   6
     10             3   6   1   5   7   4   2   8   0   9
     11             7   6   8   0   9   1   2   5   4   3
     12             9   0   2   1   5   8   6   7   3   4
     13             2   0   1   4   3   6   5   9   8   7
     14             8   6   5   7   9   1   0   2   3   4
     15             0   2   8   4   1   7   9   6   5   3
     16             6   3   5   1   8   9   7   4   0   2
     17             4   7   5   9   8   1   2   6   0   3
     18             6   9   0   5   4   1   3   8   2   7
     19             5   3   6   2   9   8   0   4   7   1
     20             9   1   5   0   6   4   2   8   3   7
     21             7   0   6   4   5   1   8   3   9   2
     22             2   1   7   5   0   6   3   9   8   4
     23             2   7   0   8   6   5   9   1   4   3
     24             5   7   3   8   9   6   1   2   0   4
     25             6   2   1   8   5   9   0   7   4   3
     26             7   1   9   2   3   0   5   6   8   4
     27             8   0   3   5   1   4   7   9   6   2
     28             0   4   6   8   7   1   5   3   2   9
     29             5   9   4   7   2   3   6   0   1   8
```

```
******************************************
*****        Data Generation        *****
*****   Thu Dec  7 14:52:10 1989    *****
******************************************

network type: 6

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bpr2.mni

binary: no               bipolar: no
continuous: yes          training required: yes
randomize records: yes

random seed:      1737
number of pixels to randomize in peaks: 6, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number      order of images in data set

      0             6   1   4   8   3   5   7   0   2   9
      1             2   1   9   8   3   4   0   5   7   6
      2             0   9   6   7   5   2   8   4   1   3
      3             6   3   9   4   2   0   8   1   7   5
      4             3   5   9   2   0   4   8   6   1   7
      5             2   0   9   4   8   6   1   7   3   5
      6             4   8   3   5   9   2   7   1   6   0
      7             0   7   1   5   2   3   6   9   4   8
      8             0   7   4   6   5   8   2   3   1   9
      9             7   6   4   5   9   1   2   0   8   3
     10             0   8   6   1   7   4   9   5   3   2
     11             9   0   2   8   6   5   3   4   7   1
     12             4   8   7   9   2   5   3   0   1   6
     13             7   4   1   0   5   3   8   2   9   6
     14             1   4   2   0   9   3   5   8   7   6
     15             1   2   9   3   8   0   6   7   4   5
     16             4   6   5   8   9   0   7   3   1   2
     17             6   2   4   1   3   5   0   9   8   7
     18             6   4   0   8   7   5   9   1   2   3
     19             4   6   9   0   5   1   8   3   7   2
     20             4   3   8   5   2   0   6   7   1   9
     21             3   4   2   9   0   5   8   7   1   6
     22             3   0   7   4   5   8   2   1   9   6
     23             1   9   8   5   6   2   0   3   7   4
     24             2   7   8   1   9   0   4   3   5   6
     25             2   8   4   0   3   7   5   1   6   9
     26             4   0   3   9   7   6   5   8   1   2
     27             3   4   0   1   8   5   6   9   2   7
     28             6   7   3   0   5   2   8   9   1   4
     29             5   8   1   9   6   7   0   4   2   3
```

```
****************************************
*****       Data Generation        *****
*****   Thu Dec  7 14:54:08 1989   *****
****************************************

network type: 6

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bpr3.mni

binary: no                bipolar: no
continuous: yes           training required: yes
randomize records: yes

random seed:       2711
number of pixels to randomize in peaks: 9, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number      order of images in data set

      0               7   0   2   5   6   4   3   8   9   1
      1               1   7   6   4   9   3   2   8   5   0
      2               4   5   9   0   8   3   1   2   6   7
      3               7   4   8   6   1   9   3   2   5   0
      4               6   2   0   8   3   1   9   4   5   7
      5               6   8   5   2   1   0   4   7   3   9
      6               4   7   9   1   2   3   8   5   6   0
      7               8   2   3   5   7   6   4   1   9   0
      8               6   2   9   3   1   5   0   7   8   4
      9               5   4   9   3   2   6   8   1   7   0
     10               8   7   4   2   3   5   0   1   6   9
     11               0   9   2   7   1   8   6   5   3   4
     12               9   2   4   6   1   3   8   7   5   0
     13               5   9   3   1   0   8   7   2   4   6
     14               1   4   2   5   3   9   8   0   7   6
     15               8   3   5   9   7   4   2   1   6   0
     16               0   4   6   9   5   2   7   3   8   1
     17               8   2   5   1   4   7   3   9   6   0
     18               8   0   9   3   7   1   4   5   2   6
     19               1   0   5   6   8   4   9   2   7   3
     20               4   8   5   6   2   3   0   1   9   7
     21               2   0   8   6   4   9   5   3   1   7
     22               7   3   9   5   6   0   8   1   2   4
     23               0   8   9   5   2   7   3   6   1   4
     24               1   4   5   2   7   0   8   6   3   9
     25               2   4   8   9   7   3   0   6   5   1
     26               1   8   3   7   0   9   4   6   5   2
     27               9   1   5   6   7   0   3   4   8   2
     28               4   1   3   6   0   5   2   8   7   9
     29               2   3   0   9   7   6   4   1   5   8
```

```
******************************************
*****        Data Generation        *****
*****  Thu Dec  7 14:56:52 1989     *****
******************************************

network type: 6

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bpr4.nni

binary: no                    bipolar: no
continuous: yes               training required: yes
randomize records: yes

random seed:      5929
number of pixels to randomize in peaks: 12, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number       order of images in data set

      0               7   1   5   4   8   6   9   2   3   0
      1               1   6   0   5   3   8   9   4   2   7
      2               9   3   5   1   0   4   7   6   2   8
      3               5   1   3   2   8   9   7   6   0   4
      4               3   5   1   0   4   2   6   9   8   7
      5               3   8   7   4   2   9   5   1   0   6
      6               9   7   5   0   2   3   8   6   4   1
      7               1   5   3   8   4   0   7   9   6   2
      8               5   4   6   8   7   2   3   1   9   0
      9               8   0   4   1   7   3   2   6   9   5
     10               7   8   2   6   4   5   1   9   0   3
     11               9   7   4   1   0   5   2   8   3   6
     12               5   9   2   7   1   3   0   6   8   4
     13               7   9   8   6   0   2   1   5   4   3
     14               0   9   5   1   8   7   3   2   6   4
     15               5   8   3   2   7   0   1   9   4   6
     16               6   5   1   2   0   4   7   3   8   9
     17               7   4   9   0   5   1   3   6   2   8
     18               3   6   9   8   1   2   7   0   4   5
     19               2   7   4   1   0   9   5   3   8   6
     20               3   7   2   6   8   5   4   0   1   9
     21               1   2   3   0   5   7   6   4   9   8
     22               9   0   2   8   7   3   6   1   4   5
     23               2   5   3   4   6   1   0   9   8   7
     24               5   8   4   1   9   6   3   2   7   0
     25               3   4   8   9   2   5   6   1   0   7
     26               8   5   9   4   1   3   6   7   0   2
     27               3   2   5   4   0   9   1   6   7   8
     28               2   7   9   8   4   1   3   5   6   0
     29               8   0   6   2   9   1   5   3   4   7
```

D.5.3 Test Results Logs

(a) Results after 902 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 15:26:46 1989   *****
****************************************

network type: 6

expected values file: bp3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       1          1,  2,  3,  6,  7,  8,  9, 10, 11, 12, 13
       1         14, 17, 18, 19, 20, 21, 23, 24, 26, 27, 28
       1         29, 30, 31, 32, 33, 35, 36, 37, 38, 40, 42
       1         43, 44, 45, 47, 48, 49, 50, 52, 53, 54, 55
       1         57, 58, 59, 60, 61, 62, 64, 65, 66, 68, 69
       1         70, 71, 72, 73, 74, 75, 76, 77, 79, 81, 82
       1         84, 85, 86, 87, 88, 89, 91, 92, 93, 94, 96
       1         97, 98, 99,101,102,103,105,106,107,108,109
       1        111,112,113,114,115,116,117,118,121,122,125
       1        126,127,128,129,130,131,132,133,134,136,137
       1        139,140,141,143,144,145,146,147,149,150,151
       1        152,153,155,156,158,159,160,161,162,163,164
       1        166,168,169,170,171,173,175,176,177,178,179
       1        180,181,183,184,185,186,187,188,189,191,193
       1        194,195,196,198,199,200,202,203,204,205,207
       1        208,209,210,211,212,213,214,215,217,218,220
       1        221,222,223,225,226,227,228,230,231,232,233
       1        234,235,237,238,239,241,242,243,245,246,247
       1        248,249,251,253,254,255,256,257,259,260,261
       1        262,263,266,267,268,269,270,271,272,273,274
       1        275,276,277,279,281,282,283,285,286,287,288
       1        290,291,292,293,294,295,296,297,298
number correct: 60, total input: 300, per cent correct: 20.0
```

(b) Results after 1803 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 15:41:38 1989   *****
****************************************

network type: 6

expected values file: bp1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Detailed Error Reporting Disabled

number correct: 180, total input: 300, per cent correct: 60.0
```

(c) Results after 2704 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 15:50:36 1989   *****
****************************************
```

```
network type: 6

expected values file: bp1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       1         4,  5,  8, 12, 14, 17, 21, 23, 25, 33, 34
       1        38, 44, 45, 50, 55, 57, 59, 63, 64, 65, 72
       1        75, 76, 81, 82, 87, 96, 97, 99,104,109,110
       1       112,117,119,124,128,129,131,133,135,142,145
       1       148,151,156,160,164,166,167,171,172,173,181
       1       184,190,194,198,200,201,204,207,216,217,220
       1       223,227,229,233,236,239,242,245,250,253,255
       1       259,262,266,269,275,279,280,281,283,290,293
       1       296,297
number correct: 210, total input: 300, per cent correct: 70.0
```

(d) Results after 3605 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 15:57:50 1989   *****
****************************************

network type: 6

expected values file: bp2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Detailed Error Reporting Disabled

number correct: 210, total input: 300, per cent correct: 70.0
```

(e) Results after 4506 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 16:04:40 1989   *****
****************************************

network type: 6

expected values file: bp5.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       2         2, 18, 29, 38, 47, 59, 68, 71, 84, 92,104
       2       118,127,134,148,158,169,173,188,200,201,213
       2       223,232,245,255,261,279,285,291
number correct: 270, total input: 300, per cent correct: 90.0
```

(f) Results after 5407 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Thu Dec  7 16:11:36 1989   *****
```

```
****************************************

network type: 6

expected values file: bp1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       1          4,  5,  8, 12, 14, 17, 21, 23, 25, 33, 34
       1         38, 44, 45, 50, 55, 57, 59, 63, 64, 65, 72
       1         75, 76, 81, 82, 87, 96, 97, 99,104,109,110
       1        112,117,119,124,128,129,131,133,135,142,145
       1        148,151,156,160,164,166,167,171,172,173,181
       1        184,190,194,198,200,201,204,207,216,217,220
       1        223,227,229,233,236,239,242,245,250,253,255
       1        259,262,266,269,275,279,280,281,283,290,293
       1        296,297
number correct: 210, total input: 300, per cent correct: 70.0
```

(g) Results after 6308 Learning Trials

```
****************************************
*****         Data Comparison      *****
*****    Thu Dec  7 16:18:10 1989  *****
****************************************

network type: 6

expected values file: bp3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       1         10, 14, 28, 35, 42, 53, 66, 76, 81, 98,102
       1        113,126,140,149,158,163,178,183,194,203,215
       1        223,234,249,254,268,273,290,295
number correct: 270, total input: 300, per cent correct: 90.0
```

(h) Results after 7209 Learning Trials

```
****************************************
*****         Data Comparison      *****
*****    Thu Dec  7 16:25:12 1989  *****
****************************************

network type: 6

expected values file: bp2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000


number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****         Data Comparison      *****
*****    Thu Dec  7 16:25:50 1989  *****
****************************************

network type: 6
```

```
expected values file: bp2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

      1        10, 16, 27, 39, 42, 55, 67, 73, 85, 97,103
      1       120,123,139,149,154,161,171,188,197,201,217
      1       228,240,249,255,268,277,282,298
number correct: 270, total input: 300, per cent correct: 90.0
```

(i) Results after 8110 Learning Trials

```
*****************************************
*****        Data Comparison        *****
*****   Thu Dec  7 16:41:16 1989    *****
*****************************************

network type: 6

expected values file: bp5.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000


number correct: 300, total input: 300, per cent correct: 100.0

*****************************************
*****        Data Comparison        *****
*****   Thu Dec  7 16:42:40 1989    *****
*****************************************

network type: 6

expected values file: bp5.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000


number correct: 300, total input: 300, per cent correct: 100.0


*****************************************
*****        Data Comparison        *****
*****   Fri Dec  8 08:53:34 1989    *****
*****************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

      2        15
      1        21
      3        22
      2        38
      1        48, 58
      2        62, 65
      1        68
      2        72
      1        78
      2        82
      1        85, 92
      2        95
      1       105,137,153,158
      2       159
      1       167,172
      2       191
      1       215
      2       218
      1       223,228
      2       232
      1       277,285,294
number correct: 269, total input: 300, per cent correct: 89.7

****************************************
*****        Data Comparison      *****
*****   Fri Dec  8 08:54:38 1989  *****
****************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

      1         5
      2        15
      1        21
      3        22
      2        38, 48
      1        58
      2        62
      1        63
      2        65
      1        68
      2        72
      1        78, 79
      2        82
      1        85
      2        92, 95
      1       101,105,137,138
      2       153
      1       156
      2       158,159
      1       167,172
      2       182
      1       187
      2       191
      1       198,215
      2       218
      1       223
      2       228,232
      1       241,245,255,277,285
      2       294
number correct: 257, total input: 300, per cent correct: 85.7

****************************************
*****        Data Comparison      *****
*****   Fri Dec  8 08:56:50 1989  *****
****************************************
```

D. BACK PROPAGATION LOGS D.

```
network type: 6

expected values file: bpr2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Detailed Error Reporting Disabled

number correct: 231, total input: 300, per cent correct: 77.0

*****************************************
*****        Data Comparison        *****
*****    Fri Dec  8 08:57:38 1989   *****
*****************************************

network type: 6

expected values file: bpr2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 212, total input: 300, per cent correct: 70.7

*****************************************
*****        Data Comparison        *****
*****    Fri Dec  8 08:59:54 1989   *****
*****************************************

network type: 6

expected values file: bpr3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Detailed Error Reporting Disabled

number correct: 204, total input: 300, per cent correct: 68.0

*****************************************
*****        Data Comparison        *****
*****    Fri Dec  8 09:00:56 1989   *****
*****************************************

network type: 6

expected values file: bpr3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 185, total input: 300, per cent correct: 61.7

*****************************************
*****        Data Comparison        *****
*****    Fri Dec  8 09:02:44 1989   *****
*****************************************

network type: 6

expected values file: bpr4.nni
actual values file: bkpstd.nno
```

```
error tolerance during comparison: 0.310000

Detailed Error Reporting Disabled

number correct: 181, total input: 300, per cent correct: 60.3

****************************************
*****         Data Comparison      *****
*****    Fri Dec  8 09:03:50 1989  *****
****************************************

network type: 6

expected values file: bpr4.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 159, total input: 300, per cent correct: 53.0
```

(j) Results after 10512 Learning Trials

```
****************************************
*****         Data Comparison      *****
*****    Fri Dec  8 09:23:44 1989  *****
****************************************

network type: 6

expected values file: bp4.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000


number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****         Data Comparison      *****
*****    Fri Dec  8 09:26:48 1989  *****
****************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       2        15
       1        21
       2        22, 38
       1        48, 58, 62
       2        65
       1        68
       2        72
       1        78
       2        82
       1        85, 92
       2        95
       1        105,137,153,158
       2        159
       1        167,172
       2        191
       1        198,215
       2        218
       1        223,228
       2        232
       1        277,285,294
number correct: 268, total input: 300, per cent correct: 89.3

****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 09:27:28 1989   *****
****************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

       1          5
       2         15
       1         21
       3         22
       2         38, 48
       1         58
       2         62
       1         63
       2         65
       1         68
       2         72
       1         78
       2         82
       1         85, 92
       2         95
       1        101,105,137,153
       2        158,159
       1        167,172
       2        191
       1        198,215
       2        218
       1        223
       2        228,232
       1        241,255,277,282,285,294
number correct: 262, total input: 300, per cent correct: 87.3

Note:  Logs for BPR2, BPR3 and BPR4 not available
```

(k) Results after 12013 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 09:50:54 1989   *****
****************************************

network type: 6

expected values file: bp1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000


number correct: 300, total input: 300, per cent correct: 100.0
```

```
****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 09:52:22 1989   *****
****************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       2         15
       1         21
       2         22, 38
       1         48, 62
       2         65
       1         68
       2         72
       1         78
       2         82
       1         85, 92
       2         95
       1        105,137,153,158
       2        159
       1        167,172
       2        191
       1        198,215
       2        218
       1        223,228
       2        232
       1        277,282,285,294
number correct: 268, total input: 300, per cent correct: 89.3

****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 09:53:04 1989   *****
****************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

       2         15
       1         21
       3         22
       2         38, 48
       1         58
       2         62
       1         63
       2         65
       1         68
       2         72
       1         78
       2         82
       1         85, 92
       2         95
       1        105,137,153
```

```
        2       158,159
        1       167,172
        2       191
        1       198,215
        2       218
        1       223
        2       228,232
        1       255,277
        2       282
        1       285,294
number correct: 265, total input: 300, per cent correct: 88.3

****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 09:54:52 1989   *****
****************************************

network type: 6

expected values file: bpr2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Detailed Error Reporting Disabled

number correct: 235, total input: 300, per cent correct: 78.3

****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 09:55:32 1989   *****
****************************************

network type: 6

expected values file: bpr2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 220, total input: 300, per cent correct: 73.3

****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 09:57:18 1989   *****
****************************************

network type: 6

expected values file: bpr3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Detailed Error Reporting Disabled

number correct: 208, total input: 300, per cent correct: 69.3

****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 09:57:48 1989   *****
****************************************

network type: 6

expected values file: bpr3.nni
```

D. BACK PROPAGATION LOGS D.

```
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 199, total input: 300, per cent correct: 66.3

*****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 09:59:26 1989   *****
*****************************************

network type: 6

expected values file: bpr4.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Detailed Error Reporting Disabled

number correct: 186, total input: 300, per cent correct: 62.0

*****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 09:59:56 1989   *****
*****************************************

network type: 6

expected values file: bpr4.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 169, total input: 300, per cent correct: 56.3
```

(1) Results after 15015 Learning Trials

```
*****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 10:17:02 1989   *****
*****************************************

network type: 6

expected values file: bp3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000


number correct: 300, total input: 300, per cent correct: 100.0

*****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 10:18:38 1989   *****
*****************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000
```

D. BACK PROPAGATION LOGS D.

```
Number of Errors  Record Number
  per Image

      2         15
      1         21
      2         22, 38
      1         48, 62
      2         65
      1         68
      2         72
      1         78
      2         82
      1         85, 92
      2         95
      1         105,137,153
      2         159
      1         167,172
      2         191
      1         198,215
      2         218
      1         223,228
      2         232
      1         277
      2         282
      1         285,294
number correct: 269, total input: 300, per cent correct: 89.7

*******************************************
*****        Data Comparison         *****
*****   Fri Dec  8 10:19:14 1989     *****
*******************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

      2         15
      1         21
      2         22, 38, 48
      1         58
      2         62, 65
      1         68
      2         72
      1         78
      2         82
      1         85, 92
      2         95
      1         105,137,153,158
      2         159
      1         167,172
      2         191
      1         198,215
      2         218
      1         223,228
      2         232
      1         277
      2         282
      1         285,294
number correct: 267, total input: 300, per cent correct: 89.0

*******************************************
```

```
*****        Data Comparison        *****
*****   Fri Dec  8 10:21:18 1989    *****
*****************************************

network type: 6

expected values file: bpr2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       2        5,  7, 18, 25, 28, 47, 53
       1        60, 61
       2        64, 69
       1        72
       2        74, 75
       1        82
       2        85, 88
       1        91
       2        94
       1        108,116,119,121,123,126
       2        132
       1        134,135
       2        137,147
       1        149
       2        163
       1        164,176
       2        182
       1        185,187,191
       2        197
       1        199,208
       2        214,216,223
       1        224,225,233
       2        234
       1        239,240
       2        248
       1        252,256
       2        257,261
       1        265
       2        268
       1        275
       3        277
       1        281,282
       2        285
       1        287
       2        291
number correct: 236, total input: 300, per cent correct: 78.7

*****************************************
*****        Data Comparison        *****
*****   Fri Dec  8 10:21:56 1989    *****
*****************************************

network type: 6

expected values file: bpr2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 220, total input: 300, per cent correct: 73.3

*****************************************
```

```
*****        Data Comparison        *****
*****    Fri Dec  8 10:23:38 1989   *****
****************************************

network type: 6

expected values file: bpr3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Detailed Error Reporting Disabled

number correct: 212, total input: 300, per cent correct: 70.7

****************************************
*****        Data Comparison        *****
*****    Fri Dec  8 10:24:18 1989   *****
****************************************

network type: 6

expected values file: bpr3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 203, total input: 300, per cent correct: 67.7

****************************************
*****        Data Comparison        *****
*****    Fri Dec  8 10:25:56 1989   *****
****************************************

network type: 6

expected values file: bpr4.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Detailed Error Reporting Disabled

number correct: 187, total input: 300, per cent correct: 62.3

****************************************
*****        Data Comparison        *****
*****    Fri Dec  8 10:26:26 1989   *****
****************************************

network type: 6

expected values file: bpr4.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Detailed Error Reporting Disabled

number correct: 170, total input: 300, per cent correct: 56.7
```

(m) Results after 19518 Learning Trials

```
****************************************
*****        Data Comparison        *****
*****    Fri Dec  8 10:50:58 1989   *****
```

```
****************************************

network type: 6

expected values file: bp2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000


number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****         Data Comparison       *****
*****   Fri Dec  8 10:52:36 1989    *****
****************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       2        15
       1        21
       2        22, 38
       1        48, 62
       2        65
       1        68
       2        72
       1        78
       2        82
       1        85, 92
       2        95
       1        105,137,153
       2        159
       1        167,172
       2        191
       1        198,215
       2        218
       1        223,228
       2        232
       1        277
       2        282
       1        285,294
number correct: 269, total input: 300, per cent correct: 89.7

****************************************
*****         Data Comparison       *****
*****   Fri Dec  8 10:53:14 1989    *****
****************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

       2        15
       1        21
       2        22, 38, 48
       1        58
       2        62, 65
       1        68
       2        72
       1        78
       2        82
       1        85, 92
       2        95
       1       105,137,153,158
       2       159
       1       167,172
       2       191,198
       1       215
       2       218
       1       223,228
       2       232
       1       277
       2       282
       1       285,294
number correct: 267, total input: 300, per cent correct: 89.0

****************************************
*****       Data Comparison        *****
*****   Fri Dec  8 10:55:06 1989   *****
****************************************

network type: 6

expected values file: bpr2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       2         5,  7, 18, 25, 28, 47, 53
       1        60, 61
       2        64, 69
       1        72
       2        74, 75
       1        82, 85
       2        88
       1        91
       2        94
       1       108,116,119,121,123,126
       2       132
       1       134,135
       2       137,147
       1       149
       2       163
       1       164,176
       2       182
       1       185,187,191
       2       197
       1       199,208
       2       214,216,223
       1       224,225,233
       2       234
       1       239,240
       2       248
       1       252
       2       257,261
       1       265
       2       268,277
       1       281,282
       2       285
```

```
        1        287
        2        291
number correct: 238, total input: 300, per cent correct: 79.3

****************************************
*****       Data Comparison       *****
*****   Fri Dec  8 10:57:54 1989   *****
****************************************

network type: 6

expected values file: bpr2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

        1          3
        2          5,  7, 18
        1         24
        2         25, 28
        1         31
        2         41, 47, 53
        1         60, 61
        2         64, 69
        1         72
        2         74, 75
        1         82
        2         85, 88
        1         91, 93
        2         94
        1        108,116,119,121,123,126
        2        132
        1        134,135
        2        137,147
        1        149
        2        163
        1        164,176
        2        182
        1        185
        2        187,191,197
        1        199,208
        2        214,216,223
        1        224
        2        225,230
        1        233
        2        234
        1        239,240
        2        247,248
        1        252,256
        2        257,261
        1        265
        2        268
        1        275
        3        277
        1        281,282
        2        285,287,291
number correct: 229, total input: 300, per cent correct: 76.3

****************************************
*****       Data Comparison       *****
*****   Fri Dec  8 10:59:52 1989   *****
****************************************

network type: 6
```

```
expected values file: bpr3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       1          1,  4
       2         18, 19
       1         22, 27
       2         30, 31, 33, 39
       1         44
       2         45, 49
       1         50
       2         52, 57, 60, 61
       1         62
       2         68
       1         69
       2         74
       1         75, 77, 86
       2         88
       1         91
       2         92, 94
       1        102
       2        105,106
       1        116,117
       2        128,131
       1        149,150
       2        152,155,162,163,164
       1        165
       2        167
       1        171
       2        173,178
       1        181
       2        184,188,189
       1        199,203,204,209
       2        211
       1        220,221,223
       2        224,234
       1        236,245,247
       2        253,259
       1        264,267,268
       2        269,273
       1        275,279
       2        283
       1        286,288
       2        289,290,294
       1        299
number correct: 219, total input: 300, per cent correct: 73.0

***************************************
*****        Data Comparison      *****
*****    Fri Dec  8 11:00:30 1989 *****
***************************************

network type: 6

expected values file: bpr3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

       2          1
       1          4, 12
```

```
            2        15, 18, 19, 22
            1        27
            2        30, 31, 33, 39
            1        44
            2        45, 49
            1        50
            2        52
            1        53
            2        57, 60, 61, 62, 68, 69, 74
            1        75, 77, 86
            2        88
            1        91
            2        92, 94
            1        99
            2       102,105,106
            1       116,117,121
            2       128
            1       129
            2       131
            1       137,149,150
            2       152,155,162,163,164
            1       165
            2       167,171,173,178,181,184,188,189,196
            1       199,203,204
            2       206
            1       208,209,210
            2       211
            1       220,221,223
            2       224
            1       228
            2       234
            1       236,245,247,248,250
            2       253
            1       255
            2       259
            1       264,266,267
            2       268,269,273,275
            1       279
            2       283
            1       286,288
            2       289,290,294,299
number correct: 203, total input: 300, per cent correct: 67.7

****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 11:02:48 1989   *****
****************************************

network type: 6

expected values file: bpr4.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

           1         3,  6
           2         7, 12, 14, 15, 16
           1        19, 20, 22
           2        23, 26
           1        30
           2        31, 33
           1        35
           2        37
           1        38
           2        41, 42, 45
```

```
          1        47
          2        50, 51
          1        52
          2        56, 57
          1        61, 62, 63
          2        67
          1        68, 72
          2        75, 77, 79, 80, 81
          1        82, 84, 85, 93, 95
          2        96
          1       100,102,106
          2       108,112,113
          1       116
          2       121
          1       122,124
          2       128,131
          1       133,134
          2       136
          1       138
          2       143
          1       146
          2       147
          1       155,162
          2       166
          1       167,170,171
          3       172
          1       175
          2       177,187,190
          1       193,197
          2       200
          1       202,205,207,215,216
          2       217
          1       220
          2       224
          1       227,229
          2       230
          1       232,235,240
          2       242
          1       244,249
          2       253,256,257
          1       260
          2       261,262
          1       268
          2       273,277,278
          1       279,280,285
          2       287,288,289,293
          1       295,300
number correct: 187, total input: 300, per cent correct: 62.3

****************************************
*****        Data Comparison       *****
*****   Fri Dec  8 11:03:20 1989   *****
****************************************

network type: 6

expected values file: bpr4.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.210000

Number of Errors  Record Number
  per Image

          1         3
          2         6,  7, 12, 14, 15, 16
          1        19, 20
          2        22, 23
```

D. BACK PROPAGATION LOGS D.

```
     3       26
     2       30, 31, 33
     1       35
     2       37
     1       38
     2       41, 42, 45
     1       47
     2       50, 51
     1       52
     2       56, 57, 61
     1       62
     2       63, 67, 68
     1       72
     2       75, 77, 79, 80, 81
     1       82, 84, 85
     2       87
     1       93, 95
     2       96
     1       97,100,102,106
     2      108,112,113
     1      116
     2      121
     1      122,124,126
     2      128
     3      131
     1      133,134
     2      136
     1      138
     2      143
     1      146
     2      147
     1      155,162,164
     2      166
     1      167,170,171
     3      172
     1      175
     2      177,187,190
     1      193,197
     3      200
     1      202,205,207,210,215,216
     2      217
     1      220
     2      224
     1      227
     2      229,230
     1      232
     2      233,235
     1      238,240
     2      242
     1      244,249
     2      253,256,257,260,261,262
     1      263,268
     2      273,277,278,279
     1      280,282
     2      285,287,288,289,293,295,300
number correct: 178, total input: 300, per cent correct: 59.3
```

D.6 Adaline Network Random Training (12 Peaks)

D.6.1 Data Generation Logs (Training Files)

```
****************************************
*****        Data Generation       *****
*****  Sun Dec 17 12:02:32 1989    *****
****************************************

network type: 1

input file: image
   images:    10   rows:      6   columns:     27   classes:     10
output file: adr5.nni

binary: no                bipolar: yes
continuous: no            training required: yes
randomize records: yes

random seed:      9910
number of pixels to randomize in peaks: 12, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

     0              0    8    7    6    9    3    5    4    2    1
     1              3    7    2    1    4    9    5    0    6    8
     2              6    4    7    8    2    1    3    0    5    9
     3              6    7    5    2    3    1    9    0    8    4
     4              0    3    7    9    8    5    2    1    6    4
     5              0    1    3    5    6    7    4    2    9    8
     6              6    0    8    7    1    3    9    5    2    4
     7              9    6    2    4    0    5    1    3    8    7
     8              1    3    5    6    7    9    8    0    4    2
     9              8    5    1    3    9    6    7    0    4    2
    10              9    2    4    0    5    6    8    3    7    1
    11              1    6    9    2    8    0    3    5    4    7
    12              2    0    4    6    9    3    7    5    1    8
    13              1    3    6    2    5    7    4    9    8    0
    14              3    7    6    0    8    2    9    1    5    4
    15              0    5    6    8    2    9    4    1    3    7
    16              4    1    9    0    6    8    2    7    3    5
    17              1    3    6    5    0    8    4    2    7    9
    18              5    1    9    8    7    0    4    2    6    3
    19              0    2    9    5    1    4    3    7    6    8
    20              0    2    4    6    7    3    9    1    5    8
    21              0    5    7    3    2    8    4    1    9    6
    22              3    4    0    7    5    6    8    2    1    9
    23              5    2    8    0    6    3    9    1    4    7
    24              3    6    4    8    0    2    9    5    1    7
    25              1    7    3    5    4    6    0    8    2    9
    26              5    7    8    2    9    0    1    4    3    6
    27              4    0    5    1    9    7    8    2    6    3
    28              0    7    9    6    5    2    1    4    8    3
    29              7    9    5    4    6    1    0    8    2    3
```

D. ADALINE RANDOM TRAINING LOGS (12 PEAKS) D.

```
*****************************************
*****        Data Generation        *****
*****   Sun Dec 17 12:18:32 1989    *****
*****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: adr6.nni

binary: no                 bipolar: yes
continuous: no             training required: yes
randomize records: yes

random seed:      1576
number of pixels to randomize in peaks: 12, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

     0              4   7   8   9   1   5   2   6   3   0
     1              4   9   2   5   0   8   1   3   6   7
     2              9   1   0   6   5   2   3   7   4   8
     3              6   7   2   1   8   4   9   0   5   3
     4              5   2   1   9   3   0   7   8   4   6
     5              9   6   1   4   5   3   8   2   0   7
     6              4   9   0   8   3   7   5   6   1   2
     7              9   8   7   4   6   0   2   3   5   1
     8              2   6   8   9   1   7   0   4   5   3
     9              1   4   6   3   9   0   8   7   2   5
    10              6   0   5   7   4   9   3   1   8   2
    11              1   5   3   4   7   2   0   8   9   6
    12              3   2   1   5   0   7   6   9   8   4
    13              6   9   1   0   7   4   5   2   8   3
    14              5   0   1   3   8   6   9   2   4   7
    15              2   7   9   6   0   8   4   3   5   1
    16              7   9   6   0   5   2   1   4   8   3
    17              0   3   6   5   1   8   2   4   9   7
    18              6   7   2   4   8   1   9   3   0   5
    19              4   9   2   5   7   8   0   1   6   3
    20              8   9   2   6   4   7   3   0   1   5
    21              6   3   9   7   2   8   1   0   4   5
    22              8   2   7   3   4   9   5   0   1   6
    23              7   8   5   6   3   4   9   1   2   0
    24              6   5   1   3   8   9   0   4   2   7
    25              5   0   7   2   6   3   1   9   4   8
    26              6   2   5   7   1   3   0   8   4   9
    27              8   2   9   6   0   4   1   7   3   5
    28              0   1   5   2   3   7   6   8   9   4
    29              1   6   9   5   3   7   4   0   8   2
```

D. ADALINE RANDOM TRAINING LOGS (12 PEAKS) D.

```
****************************************
*****        Data Generation       *****
*****   Sun Dec 17 12:36:18 1989   *****
****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: adr7.nni

binary: no                  bipolar: yes
continuous: no              training required: yes
randomize records: yes

random seed:     4589
number of pixels to randomize in peaks: 12, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

      0             4    3    1    7    5    2    9    8    6    0
      1             6    7    4    5    2    8    9    1    3    0
      2             1    2    8    5    9    7    3    4    0    6
      3             2    8    7    3    9    1    4    0    6    5
      4             4    0    3    2    7    6    8    5    9    1
      5             8    3    5    6    1    0    2    9    4    7
      6             4    8    0    2    9    5    7    3    1    6
      7             2    9    3    6    7    4    1    0    5    8
      8             7    0    8    4    1    5    2    3    9    6
      9             7    5    8    3    2    4    9    1    0    6
     10             3    1    7    4    9    8    0    6    2    5
     11             2    7    1    8    4    9    0    6    3    5
     12             2    0    6    7    1    8    3    4    5    9
     13             1    3    7    2    5    8    9    4    0    6
     14             6    1    8    5    9    0    2    7    3    4
     15             9    4    6    1    7    2    0    3    8    5
     16             1    0    8    4    9    7    3    6    5    2
     17             2    5    4    0    3    1    7    6    9    8
     18             6    4    5    2    7    1    3    8    9    0
     19             9    2    6    3    4    5    8    7    0    1
     20             4    0    2    3    5    7    6    9    8    1
     21             8    6    0    1    9    2    7    5    4    3
     22             7    3    4    2    9    0    8    6    5    1
     23             2    3    6    4    8    5    0    7    1    9
     24             8    0    9    5    1    4    6    2    7    3
     25             2    7    8    6    5    1    9    4    3    0
     26             7    4    2    9    6    3    8    0    5    1
     27             2    9    5    0    4    8    6    7    1    3
     28             9    0    2    7    3    4    5    6    1    8
     29             9    1    8    2    3    6    7    4    0    5
```

D. ADALINE RANDOM TRAINING LOGS (12 PEAKS) D.

```
********************************
*****     Data Generation      *****
*****  Sun Dec 17 12:51:10 1989  *****
********************************

network type: 1

input file: image
   images:    10  rows:     6  columns:    27  classes:    10
output file: adr8.nni

binary: no               bipolar: yes
continuous: no           training required: yes
randomize records: yes

random seed:     6317
number of pixels to randomize in peaks: 12, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

      0              7   3   4   9   0   2   6   1   5   8
      1              0   1   7   3   6   8   4   5   9   2
      2              4   2   8   0   1   5   7   9   3   6
      3              4   3   8   9   2   5   0   1   6   7
      4              2   1   8   0   6   5   7   9   3   4
      5              0   7   8   5   3   6   4   2   1   9
      6              7   8   0   1   6   5   3   4   2   9
      7              9   7   6   5   0   2   3   4   1   8
      8              3   7   9   8   5   1   2   6   0   4
      9              9   0   7   3   6   1   5   2   4   8
     10              3   1   6   8   0   9   7   2   4   5
     11              8   7   9   1   0   4   5   2   6   3
     12              9   8   5   6   0   3   4   2   7   1
     13              5   8   4   2   6   0   9   3   7   1
     14              7   6   5   3   2   4   1   8   0   9
     15              6   8   4   3   1   2   0   9   7   5
     16              3   1   2   7   6   5   4   9   0   8
     17              1   5   7   0   9   6   2   4   3   8
     18              1   0   8   5   2   7   4   6   3   9
     19              1   6   8   3   2   5   4   0   7   9
     20              8   7   1   5   6   9   2   4   3   0
     21              5   9   1   0   6   4   3   7   8   2
     22              5   4   8   2   6   1   9   0   7   3
     23              9   3   8   7   4   6   5   1   2   0
     24              2   6   3   5   7   8   1   4   9   0
     25              4   9   2   3   5   1   8   6   0   7
     26              7   1   6   8   5   3   9   2   4   0
     27              9   5   3   4   8   2   7   0   6   1
     28              9   2   3   5   1   0   8   4   7   6
     29              3   9   6   7   4   8   2   1   0   5
```

D. ADALINE RANDOM TRAINING LOGS (12 PEAKS) D.

```
****************************************
*****         Data Generation      *****
*****   Sun Dec 17 13:09:06 1989   *****
****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: adr9.nni

binary: no                   bipolar: yes
continuous: no               training required: yes
randomize records: yes

random seed:      7371
number of pixels to randomize in peaks: 12, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

      0             0   4   9   7   1   3   2   6   8   5
      1             8   7   0   1   3   4   6   9   2   5
      2             0   8   3   6   1   9   7   2   5   4
      3             0   6   9   4   2   1   5   8   7   3
      4             7   8   3   0   2   5   4   1   9   6
      5             3   7   9   0   2   6   5   4   8   1
      6             0   2   6   8   3   4   7   9   1   5
      7             9   2   7   0   4   5   6   8   1   3
      8             1   7   0   6   8   2   5   9   3   4
      9             1   3   4   6   0   5   7   8   2   9
     10             8   3   6   7   9   1   4   5   2   0
     11             3   5   1   8   6   9   7   4   0   2
     12             4   9   8   7   3   5   0   6   1   2
     13             5   8   4   0   7   6   9   3   2   1
     14             7   6   2   5   8   9   4   0   1   3
     15             2   7   3   6   4   1   5   9   0   8
     16             9   6   5   0   7   8   2   1   4   3
     17             4   0   7   2   6   1   9   3   8   5
     18             5   6   1   2   9   3   0   7   4   8
     19             7   8   2   4   0   1   9   3   5   6
     20             1   4   3   0   8   7   2   5   9   6
     21             9   4   0   7   6   1   3   8   5   2
     22             2   1   4   7   9   0   8   5   3   6
     23             7   2   1   5   6   0   9   8   3   4
     24             3   6   1   7   5   2   8   0   4   9
     25             8   0   4   5   2   7   6   3   1   9
     26             9   5   1   8   3   2   4   0   6   7
     27             7   5   2   6   1   3   4   0   9   8
     28             1   3   2   0   4   6   5   9   8   7
     29             3   1   2   7   4   8   6   5   9   0
```

D.6.2 Test Results Logs

(a) Results after 302 Learning Trials

Results log not available.

(b) Results after 603 Learning Trials

```
****************************************
*****       Data Comparison       *****
*****   Sun Dec 17 12:27:46 1989   *****
****************************************

network type: 1

expected values file: ad1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000


number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****       Data Comparison       *****
*****   Sun Dec 17 12:34:24 1989   *****
****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Detailed Error Reporting Disabled

number correct: 166, total input: 300, per cent correct: 55.3
```

(c) Results after 904 Learning Trials

```
****************************************
*****       Data Comparison       *****
*****   Sun Dec 17 12:45:42 1989   *****
****************************************

network type: 1

expected values file: ad1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000


number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****       Data Comparison       *****
*****   Sun Dec 17 12:49:18 1989   *****
****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000
```

```
Number of Errors  Record Number
  per Image

      1       41, 75, 77, 82,115,158,182,198,246
number correct: 291, total input: 300, per cent correct: 97.0
```

(d) Results after 1205 Learning Trials

```
****************************************
*****         Data Comparison      *****
*****   Sun Dec 17 13:02:30 1989   *****
****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      1       187,198
number correct: 298, total input: 300, per cent correct: 99.3

****************************************
*****         Data Comparison      *****
*****   Sun Dec 17 13:06:36 1989   *****
****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      1          4, 17, 23, 29, 31, 34, 35, 36, 43, 44, 45
      1         53, 57, 61, 68, 70, 71, 72, 75, 78
      2         79, 82
      1         86, 88, 95,102,103,106,110,120,122,127,128
      1        132,134,148,151,153,156,165,166,172
      2        173
      1        175,176,181,182,188,200,206,208,209,212,214
      1        215,226
      2        232
      1        234,235,239,240,246,251,252,256,257,258,269
      1        274,279,286,293,298
number correct: 227, total input: 300, per cent correct: 75.7
```

(e) Results after 3312 Learning Trials

```
****************************************
*****         Data Comparison      *****
*****   Sun Dec 17 15:14:22 1989   *****
****************************************

network type: 1

expected values file: ad1.nni
actual values file: adaline.nno
```

```
error tolerance during comparison: 0.000000


number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****         Data Comparison      *****
*****   Sun Dec 17 15:17:50 1989   *****
****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000


number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****         Data Comparison      *****
*****   Sun Dec 17 15:21:48 1989   *****
****************************************

network type: 1

expected values file: adr2.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      1         50,133,207,281
number correct: 296, total input: 300, per cent correct: 98.7

****************************************
*****         Data Comparison      *****
*****   Sun Dec 17 15:27:02 1989   *****
****************************************

network type: 1

expected values file: adr3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      1         76, 77, 84, 88, 94,132,138,158,175,238,241
      1        246,260,291,295
number correct: 285, total input: 300, per cent correct: 95.0

****************************************
*****         Data Comparison      *****
*****   Sun Dec 17 15:32:02 1989   *****
****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000
```

D. ADALINE RANDOM TRAINING LOGS (12 PEAKS) D.

```
Number of Errors  Record Number
  per Image

       1          4, 35, 36, 61
       2         71
       1         79, 86, 89,103,110,120,128,153,156,157,165
       1        176,181,200,209,212,215,223,224,228,251,256
       1        291
number correct: 272, total input: 300, per cent correct: 90.7
```

D.7 Adaline Network Random Training (24 Peaks)

D.7.1 Data Generation Logs (Training Files)

```
****************************************
*****        Data Generation      *****
*****   Mon Dec 18 09:07:00 1989  *****
****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: adr10.nni

binary: no                 bipolar: yes
continuous: no             training required: yes
randomize records: yes

random seed:      1666
number of pixels to randomize in peaks: 24, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

      0            1   2   4   6   7   3   8   5   0   9
      1            1   7   3   8   6   4   9   5   2   0
      2            1   0   2   7   6   8   3   4   9   5
      3            6   0   4   1   7   5   2   8   9   3
      4            6   9   2   1   0   3   5   8   7   4
      5            6   5   7   8   9   3   4   2   0   1
      6            6   8   9   1   2   3   7   5   4   0
      7            2   5   3   7   6   8   1   9   4   0
      8            1   6   7   5   2   0   9   4   3   8
      9            4   1   7   9   5   3   6   2   0   8
     10            0   6   9   3   8   4   7   2   1   5
     11            2   0   3   1   4   7   9   6   5   8
     12            1   6   0   3   2   5   8   7   9   4
     13            5   9   8   6   1   3   0   7   2   4
     14            5   3   7   0   8   1   9   2   6   4
     15            1   2   4   8   7   6   3   9   0   5
     16            9   0   2   7   1   8   5   4   6   3
     17            3   5   7   0   2   8   9   1   6   4
     18            3   9   5   8   2   6   7   0   4   1
     19            4   7   0   6   2   9   5   1   8   3
     20            7   9   3   4   6   8   5   0   1   2
     21            0   8   6   3   4   5   2   7   1   9
     22            2   6   1   0   7   9   3   5   8   4
     23            0   4   7   1   9   5   3   8   6   2
     24            7   0   2   3   1   4   8   6   9   5
     25            3   1   0   4   2   9   7   8   6   5
     26            0   7   1   2   9   3   4   6   5   8
     27            2   4   0   7   6   9   3   1   8   5
     28            2   1   3   6   5   8   7   0   4   9
     29            4   2   6   8   1   9   7   5   0   3
```

D. ADALINE RANDOM TRAINING LOGS (24 PEAKS) D.

```
****************************************
*****        Data Generation      *****
*****  Mon Dec 18 09:20:12 1989   *****
****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: adr11.nni

binary: no               bipolar: yes
continuous: no           training required: yes
randomize records: yes

random seed:      2333
number of pixels to randomize in peaks: 24, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number       order of images in data set

      0              9    0    4    8    7    2    5    6    1    3
      1              8    4    1    7    9    6    3    0    5    2
      2              7    6    3    8    0    2    4    5    1    9
      3              6    8    4    7    5    3    9    2    1    0
      4              4    5    8    7    2    3    9    6    1    0
      5              8    7    9    2    0    4    6    1    3    5
      6              6    7    9    3    0    1    5    2    8    4
      7              6    8    2    3    9    1    0    7    4    5
      8              1    0    5    2    7    4    9    8    6    3
      9              9    8    4    0    6    7    3    1    5    2
     10              2    8    5    3    9    4    1    7    6    0
     11              6    0    2    1    3    4    7    5    9    8
     12              2    9    4    8    6    1    7    0    5    3
     13              2    0    6    1    4    8    3    5    7    9
     14              9    2    0    3    7    5    8    4    1    6
     15              3    8    5    2    9    4    0    6    1    7
     16              2    0    5    7    6    3    9    8    1    4
     17              8    9    6    4    0    2    7    5    3    1
     18              7    3    4    0    1    9    5    6    2    8
     19              9    8    2    6    4    5    7    3    0    1
     20              0    3    8    4    7    6    9    5    2    1
     21              7    5    9    4    0    8    3    2    1    6
     22              7    8    1    4    9    2    6    3    0    5
     23              0    3    1    5    4    9    6    8    7    2
     24              9    3    7    1    4    2    0    8    6    5
     25              0    4    1    5    7    3    2    8    9    6
     26              3    0    7    1    9    2    8    5    6    4
     27              3    1    0    6    2    7    5    4    8    9
     28              9    3    8    0    4    1    6    5    7    2
     29              1    2    8    5    3    0    6    9    4    7
```

D. ADALINE RANDOM TRAINING LOGS (24 PEAKS) D.

```
****************************************
*****        Data Generation       *****
*****   Mon Dec 18 09:47:50 1989   *****
****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: adr12.nni

binary: no              bipolar: yes
continuous: no          training required: yes
randomize records: yes

random seed:     3937
number of pixels to randomize in peaks: 24, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

      0             7   0   4   5   1   9   6   3   8   2
      1             3   5   4   9   0   7   1   8   6   2
      2             8   9   7   6   5   0   3   4   1   2
      3             9   8   6   4   5   7   0   2   3   1
      4             9   7   3   0   4   1   6   2   5   8
      5             3   8   7   0   4   5   1   6   9   2
      6             8   4   1   9   5   3   0   6   2   7
      7             3   1   6   9   5   8   7   0   4   2
      8             8   7   6   1   9   2   5   4   0   3
      9             0   7   1   5   6   9   3   4   8   2
     10             4   5   2   7   1   6   0   9   3   8
     11             1   2   7   8   3   5   4   6   0   9
     12             7   1   6   2   0   5   9   3   8   4
     13             8   1   0   2   5   3   6   9   4   7
     14             0   8   9   1   7   4   3   5   6   2
     15             2   8   1   7   5   0   6   3   9   4
     16             1   7   6   4   8   9   2   3   5   0
     17             8   1   4   7   3   2   6   5   9   0
     18             3   7   5   2   1   6   0   9   4   8
     19             1   5   8   0   9   2   3   4   6   7
     20             1   2   6   7   8   5   4   9   3   0
     21             4   8   7   9   6   1   2   0   5   3
     22             8   7   2   1   5   4   6   3   0   9
     23             8   9   4   7   0   3   6   2   5   1
     24             2   5   8   4   3   9   7   6   0   1
     25             1   6   0   3   8   7   9   5   2   4
     26             2   4   1   8   5   7   0   3   6   9
     27             7   0   2   1   4   9   6   8   5   3
     28             2   0   8   3   5   6   7   1   9   4
     29             3   2   7   9   6   4   5   0   8   1
```

D. ADALINE RANDOM TRAINING LOGS (24 PEAKS) D.

```
****************************************
*****        Data Generation       *****
*****   Mon Dec 18 09:55:26 1989   *****
****************************************

network type: 1

input file: image
   images:    10  rows:     6  columns:    27  classes:    10
output file: adr13.nni

binary: no               bipolar: yes
continuous: no           training required: yes
randomize records: yes

random seed:     4111
number of pixels to randomize in peaks: 24, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

      0              2    0    7    4    5    3    6    1    8    9
      1              7    2    6    0    4    8    9    5    1    3
      2              9    6    4    8    1    2    0    5    7    3
      3              4    2    5    3    7    8    9    1    6    0
      4              4    7    6    3    5    0    9    2    1    8
      5              7    4    3    2    0    1    8    5    9    6
      6              0    3    6    2    4    9    7    8    1    5
      7              4    6    7    2    0    9    8    3    1    5
      8              8    3    6    0    9    1    4    2    7    5
      9              0    3    8    5    9    7    6    2    4    1
     10              4    1    6    8    0    7    2    3    5    9
     11              5    4    6    3    9    8    7    0    1    2
     12              9    5    3    2    1    4    6    7    8    0
     13              3    7    1    8    0    2    5    6    9    4
     14              6    8    7    0    4    3    5    2    9    1
     15              6    7    4    1    3    8    9    5    0    2
     16              9    8    0    2    4    6    7    3    5    1
     17              9    2    8    6    4    0    5    3    7    1
     18              4    2    9    6    8    0    1    7    5    3
     19              2    6    7    9    5    8    3    4    1    0
     20              6    3    2    1    4    8    0    9    7    5
     21              3    5    0    9    1    6    4    7    2    8
     22              7    4    6    1    3    0    8    9    2    5
     23              5    3    4    0    1    2    8    9    6    7
     24              4    5    2    9    6    3    7    1    0    8
     25              8    4    3    1    2    7    6    5    0    9
     26              1    3    9    0    4    7    6    5    2    8
     27              0    2    9    3    7    6    5    4    1    8
     28              1    2    8    4    3    7    5    9    6    0
     29              5    7    3    0    9    1    8    6    2    4
```

D. ADALINE RANDOM TRAINING LOGS (24 PEAKS) D.

```
*****************************************
*****        Data Generation        *****
*****   Mon Dec 18 10:04:28 1989    *****
*****************************************

network type: 1

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: adr14.nni

binary: no                  bipolar: yes
continuous: no              training required: yes
randomize records: yes

random seed:     5759
number of pixels to randomize in peaks: 24, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 30

data set number      order of images in data set

      0              7    3    2    9    8    1    5    6    4    0
      1              7    2    6    0    5    3    9    8    1    4
      2              9    6    1    7    5    8    2    0    4    3
      3              5    4    7    2    1    3    6    8    0    9
      4              4    0    1    5    9    8    3    2    6    7
      5              4    6    2    9    3    8    0    5    1    7
      6              8    5    0    3    1    6    7    2    4    9
      7              2    6    8    5    7    3    1    9    4    0
      8              9    1    8    3    0    5    7    4    6    2
      9              2    8    0    6    3    1    9    7    4    5
     10              1    3    2    8    9    7    5    6    4    0
     11              8    9    4    1    3    7    0    5    2    6
     12              9    7    8    2    3    4    1    6    5    0
     13              8    3    1    4    5    6    2    9    0    7
     14              2    8    0    3    1    6    9    4    5    7
     15              6    8    9    0    5    7    2    4    3    1
     16              6    8    3    2    0    9    4    7    5    1
     17              6    7    2    8    3    9    5    0    1    4
     18              9    5    6    0    1    7    3    2    8    4
     19              1    7    9    5    2    0    8    4    3    6
     20              2    4    6    0    7    5    3    1    8    9
     21              1    9    5    4    8    0    6    2    7    3
     22              1    9    0    7    6    8    2    5    4    3
     23              2    3    6    5    8    7    1    0    9    4
     24              5    2    1    7    6    8    0    3    9    4
     25              7    9    4    6    2    3    1    0    8    5
     26              5    4    6    2    7    3    0    1    8    9
     27              5    6    7    2    3    9    1    8    4    0
     28              1    9    5    7    4    6    3    0    8    2
     29              0    8    5    9    3    6    2    1    4    7
```

D.7.2 Test Results Logs

(a) Results after 302 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 09:18:02 1989   *****
****************************************

network type: 1

expected values file: ad1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Detailed Error Reporting Disabled

number correct: 150, total input: 300, per cent correct: 50.0
```

(b) Results after 603 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 09:41:46 1989   *****
****************************************

network type: 1

expected values file: ad1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000


number correct: 300, total input: 300, per cent correct: 100.0

****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 09:45:52 1989   *****
****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Detailed Error Reporting Disabled

number correct: 173, total input: 300, per cent correct: 57.7
```

(c) Results after 3312 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 10:46:44 1989   *****
****************************************

network type: 1

expected values file: ad1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000
```

D. ADALINE RANDOM TRAINING LOGS (24 PEAKS) D.

```
number correct: 300, total input: 300, per cent correct: 100.0

*****************************************
*****         Data Comparison      *****
*****   Mon Dec 18 10:53:32 1989   *****
*****************************************

network type: 1

expected values file: adr1.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000


number correct: 300, total input: 300, per cent correct: 100.0

*****************************************
*****         Data Comparison      *****
*****   Mon Dec 18 10:57:16 1989   *****
*****************************************

network type: 1

expected values file: adr2.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      1         50
number correct: 299, total input: 300, per cent correct: 99.7

*****************************************
*****         Data Comparison      *****
*****   Mon Dec 18 11:01:00 1989   *****
*****************************************

network type: 1

expected values file: adr3.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      1         44, 76, 88,236,246,283,296
number correct: 293, total input: 300, per cent correct: 97.7

*****************************************
*****         Data Comparison      *****
*****   Mon Dec 18 11:04:48 1989   *****
*****************************************

network type: 1

expected values file: adr4.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image
```

D. ADALINE RANDOM TRAINING LOGS (24 PEAKS) D.

```
        1        29, 53,106,127,128,173,188,208,214,239,240
number correct: 289, total input: 300, per cent correct: 96.3
```

D.8 Back Propagation Network Random Training (24 Peaks)

D.8.1 Data Generation Logs (Training Files)

```
****************************************
*****        Data Generation       *****
*****  Mon Dec 18 14:39:24 1989    *****
****************************************

network type: 6

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bpr5.nni

binary: no                  bipolar: no
continuous: yes             training required: yes
randomize records: yes

random seed:      1666
number of pixels to randomize in peaks: 24, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number       order of images in data set

      0                 1   2   4   6   7   3   8   5   0   9
      1                 1   7   3   8   6   4   9   5   2   0
      2                 1   0   2   7   6   8   3   4   9   5
      3                 6   0   4   1   7   5   2   8   9   3
      4                 6   9   2   1   0   3   5   8   7   4
      5                 6   5   7   8   9   3   4   2   0   1
      6                 6   8   9   1   2   3   7   5   4   0
      7                 2   5   3   7   6   8   1   9   4   0
      8                 1   6   7   5   2   0   9   4   3   8
      9                 4   1   7   9   5   3   6   2   0   8
     10                 0   6   9   3   8   4   7   2   1   5
     11                 2   0   3   1   4   7   9   6   5   8
     12                 1   6   0   3   2   5   8   7   9   4
     13                 5   9   8   6   1   3   0   7   2   4
     14                 5   3   7   0   8   1   9   2   6   4
     15                 1   2   4   8   7   6   3   9   0   5
     16                 9   0   2   7   1   8   5   4   6   3
     17                 3   5   7   0   2   8   9   1   6   4
     18                 3   9   5   8   2   6   7   0   4   1
     19                 4   7   0   6   2   9   5   1   8   3
     20                 7   9   3   4   6   8   5   0   1   2
     21                 0   8   6   3   4   5   2   7   1   9
     22                 2   6   1   0   7   9   3   5   8   4
     23                 0   4   7   1   9   5   3   8   6   2
     24                 7   0   2   3   1   4   8   6   9   5
     25                 3   1   0   4   2   9   7   8   6   5
     26                 0   7   1   2   9   3   4   6   5   8
     27                 2   4   0   7   6   9   3   1   8   5
     28                 2   1   3   6   5   8   7   0   4   9
     29                 4   2   6   8   1   9   7   5   0   3
```

D. BACK PROPAGATION RANDOM TRAINING LOGS (24 PEAKS) D.

```
****************************************
*****        Data Generation       *****
*****   Mon Dec 18 14:43:52 1989   *****
****************************************

network type: 6

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bpr6.mni

binary: no                  bipolar: no
continuous: yes             training required: yes
randomize records: yes

random seed:     2333
number of pixels to randomize in peaks: 24, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number     order of images in data set

       0            9   0   4   8   7   2   5   6   1   3
       1            8   4   1   7   9   6   3   0   5   2
       2            7   6   3   8   0   2   4   5   1   9
       3            6   8   4   7   5   3   9   2   1   0
       4            4   5   8   7   2   3   9   6   1   0
       5            8   7   9   2   0   4   6   1   3   5
       6            6   7   9   3   0   1   5   2   8   4
       7            6   8   2   3   9   1   0   7   4   5
       8            1   0   5   2   7   4   9   8   6   3
       9            9   8   4   0   6   7   3   1   5   2
      10            2   8   5   3   9   4   1   7   6   0
      11            6   0   2   1   3   4   7   5   9   8
      12            2   9   4   8   6   1   7   0   5   3
      13            2   0   6   1   4   8   3   5   7   9
      14            9   2   0   3   7   5   8   4   1   6
      15            3   8   5   2   9   4   0   6   1   7
      16            2   0   5   7   6   3   9   8   1   4
      17            8   9   6   4   0   2   7   5   3   1
      18            7   3   4   0   1   9   5   6   2   8
      19            9   8   2   6   4   5   7   3   0   1
      20            0   3   8   4   7   6   9   5   2   1
      21            7   5   9   4   0   8   3   2   1   6
      22            7   8   1   4   9   2   6   3   0   5
      23            0   3   1   5   4   9   6   8   7   2
      24            9   3   7   1   4   2   0   8   6   5
      25            0   4   1   5   7   3   2   8   9   6
      26            3   0   7   1   9   2   8   5   6   4
      27            3   1   0   6   2   7   5   4   8   9
      28            9   3   8   0   4   1   6   5   7   2
      29            1   2   8   5   3   0   6   9   4   7
```

D. BACK PROPAGATION RANDOM TRAINING LOGS (24 PEAKS) D.

```
*****************************************
*****        Data Generation        *****
*****   Mon Dec 18 14:46:48 1989    *****
*****************************************

network type: 6

input file: image
   images:    10   rows:     6   columns:    27   classes:    10
output file: bpr7.nni

binary: no               bipolar: no
continuous: yes          training required: yes
randomize records: yes

random seed:     3937
number of pixels to randomize in peaks: 24, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number      order of images in data set

      0              7   0   4   5   1   9   6   3   8   2
      1              3   5   4   9   0   7   1   8   6   2
      2              8   9   7   6   5   0   3   4   1   2
      3              9   8   6   4   5   7   0   2   3   1
      4              9   7   3   0   4   1   6   2   5   8
      5              3   8   7   0   4   5   1   6   9   2
      6              8   4   1   9   5   3   0   6   2   7
      7              3   1   6   9   5   8   7   0   4   2
      8              8   7   6   1   9   2   5   4   0   3
      9              0   7   1   5   6   9   3   4   8   2
     10              4   5   2   7   1   6   0   9   3   8
     11              1   2   7   8   3   5   4   6   0   9
     12              7   1   6   2   0   5   9   3   8   4
     13              8   1   0   2   5   3   6   9   4   7
     14              0   8   9   1   7   4   3   5   6   2
     15              2   8   1   7   5   0   6   3   9   4
     16              1   7   6   4   8   9   2   3   5   0
     17              8   1   4   7   3   2   6   5   9   0
     18              3   7   5   2   1   6   0   9   4   8
     19              1   5   8   0   9   2   3   4   6   7
     20              1   2   6   7   8   5   4   9   3   0
     21              4   8   7   9   6   1   2   0   5   3
     22              8   7   2   1   5   4   6   3   0   9
     23              8   9   4   7   0   3   6   2   5   1
     24              2   5   8   4   3   9   7   6   0   1
     25              1   6   0   3   8   7   9   5   2   4
     26              2   4   1   8   5   7   0   3   6   9
     27              7   0   2   1   4   9   6   8   5   3
     28              2   0   8   3   5   6   7   1   9   4
     29              3   2   7   9   6   4   5   0   8   1
```

D. BACK PROPAGATION RANDOM TRAINING LOGS (24 PEAKS) D.

```
****************************************
*****       Data Generation        *****
*****  Mon Dec 18 14:50:02 1989    *****
****************************************

network type: 6

input file: image
   images:    10  rows:     6  columns:    27  classes:    10
output file: bpr8.nni

binary: no                  bipolar: no
continuous: yes             training required: yes
randomize records: yes

random seed:     4111
number of pixels to randomize in peaks: 24, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number      order of images in data set

       0             2   0   7   4   5   3   6   1   8   9
       1             7   2   6   0   4   8   9   5   1   3
       2             9   6   4   8   1   2   0   5   7   3
       3             4   2   5   3   7   8   9   1   6   0
       4             4   7   6   3   5   0   9   2   1   8
       5             7   4   3   2   0   1   8   5   9   6
       6             0   3   6   2   4   9   7   8   1   5
       7             4   6   7   2   0   9   8   3   1   5
       8             8   3   6   0   9   1   4   2   7   5
       9             0   3   8   5   9   7   6   2   4   1
      10             4   1   6   8   0   7   2   3   5   9
      11             5   4   6   3   9   8   7   0   1   2
      12             9   5   3   2   1   4   6   7   8   0
      13             3   7   1   8   0   2   5   6   9   4
      14             6   8   7   0   4   3   5   2   9   1
      15             6   7   4   1   3   8   9   5   0   2
      16             9   8   0   2   4   6   7   3   5   1
      17             9   2   8   6   4   0   5   3   7   1
      18             4   2   9   6   8   0   1   7   5   3
      19             2   6   7   9   5   8   3   4   1   0
      20             6   3   2   1   4   8   0   9   7   5
      21             3   5   0   9   1   6   4   7   2   8
      22             7   4   6   1   3   0   8   9   2   5
      23             5   3   4   0   1   2   8   9   6   7
      24             4   5   2   9   6   3   7   1   0   8
      25             8   4   3   1   2   7   6   5   0   9
      26             1   3   9   0   4   7   6   5   2   8
      27             0   2   9   3   7   6   5   4   1   8
      28             1   2   8   4   3   7   5   9   6   0
      29             5   7   3   0   9   1   8   6   2   4
```

```
****************************************
*****        Data Generation       *****
*****   Mon Dec 18 14:53:18 1989   *****
****************************************

network type: 6

input file: image
   images:    10  rows:     6  columns:    27  classes:    10
output file: bpr9.nni

binary: no                  bipolar: no
continuous: yes             training required: yes
randomize records: yes

random seed:     5759
number of pixels to randomize in peaks: 24, total pixels: 162
pixel scale factor: 2.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 30

data set number      order of images in data set

      0              7   3   2   9   8   1   5   6   4   0
      1              7   2   6   0   5   3   9   8   1   4
      2              9   6   1   7   5   8   2   0   4   3
      3              5   4   7   2   1   3   6   8   0   9
      4              4   0   1   5   9   8   3   2   6   7
      5              4   6   2   9   3   8   0   5   1   7
      6              8   5   0   3   1   6   7   2   4   9
      7              2   6   8   5   7   3   1   9   4   0
      8              9   1   8   3   0   5   7   4   6   2
      9              2   8   0   6   3   1   9   7   4   5
     10              1   3   2   8   9   7   5   6   4   0
     11              8   9   4   1   3   7   0   5   2   6
     12              9   7   8   2   3   4   1   6   5   0
     13              8   3   1   4   5   6   2   9   0   7
     14              2   8   0   3   1   6   9   4   5   7
     15              6   8   9   0   5   7   2   4   3   1
     16              6   8   3   2   0   9   4   7   5   1
     17              6   7   2   8   3   9   5   0   1   4
     18              9   5   6   0   1   7   3   2   8   4
     19              1   7   9   5   2   0   8   4   3   6
     20              2   4   6   0   7   5   3   1   8   9
     21              1   9   5   4   8   0   6   2   7   3
     22              1   9   0   7   6   8   2   5   4   3
     23              2   3   6   5   8   7   1   0   9   4
     24              5   2   1   7   6   8   0   3   9   4
     25              7   9   4   6   2   3   1   0   8   5
     26              5   4   6   2   7   3   0   1   8   9
     27              5   6   7   2   3   9   1   8   4   0
     28              1   9   5   7   4   6   3   0   8   2
     29              0   8   5   9   3   6   2   1   4   7
```

D.8.2 Test Results Logs

(a) Results after 10212 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 15:39:58 1989   *****
****************************************

network type: 6

expected values file: bp1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       1          4,  5,  6,  7, 11, 12, 14, 18, 21, 22, 23
       1         26, 31, 34, 38, 40, 44, 45, 46, 47, 54, 57
       1         58, 59, 61, 63, 65, 68, 72, 76, 77, 78, 81
       1         82, 89, 90, 93, 95, 96, 97,101,103,109,110
       1        111,112,118,119,127,128,129,130,131,133,134
       1        136,141,142,145,146,151,156,157,158,161,164
       1        167,170,171,173,175,176,184,185,188,190,191
       1        194,196,198,204,206,207,209,211,216,217,218
       1        222,223,229,230,231,232,233,236,245,247,248
       1        250,253,255,256,260,262,264,268,269,274,276
       1        279,280,282,283,284,290,291,293,297,299
number correct: 180, total input: 300, per cent correct: 60.0

****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 15:43:08 1989   *****
****************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       1          2,  5,  8,  9, 12, 15, 18, 19, 21, 22, 24
       1         25, 31, 33, 35, 38, 41, 42, 47, 49, 52, 53
       1         58, 59, 63, 64, 66, 68, 71, 75, 78, 80, 82
       1         85, 89, 90, 93, 95, 98,100,102,104,105,110
       1        111,112,115,118,121,125,127,128,136,137,138
       1        140,142,143,144,145,156,157,158,159,161,163
       1        166,167,172,173,174,178,181,182,184,190,191
       1        193,195,199,201,203,205,209,210,211,213,215
       1        219,223,224,226,228,232,235,236,237,241,242
       1        245,246,251,255,256,258,261,263,267,268,274
       1        277,278,279,283,285,287,290,291,292,294,297
number correct: 179, total input: 300, per cent correct: 59.7

****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 15:46:08 1989   *****
****************************************

network type: 6
```

```
expected values file: bpr2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       1         1,  6,  7, 10, 13, 18, 19, 20, 22, 23, 24
       1        25, 31, 33, 39, 40, 42, 43, 48, 50, 53, 56
       1        58, 60, 64, 65, 67, 69, 72, 74, 77, 78, 82
       1        84, 85, 90, 91, 92, 94, 95,103,105,107,108
       1       111,115,116,119,123,124,126,130,131,135,139
       1       140,145,147,149,150,153,157,158,160,162,163
       1       165,167,171,172,176,178,180,181,185,186,187
       1       192,193,195,199,204,207,208,210,214,216,218
       1       220,223,225,229,230,232,234,235,239,242,245
       1       249,250,256,257,259,260,264,265,266,267,276
       1       277,278,280,281,282,285,288,291,294,295,296
number correct: 179, total input: 300, per cent correct: 59.7

****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 15:48:16 1989   *****
****************************************

network type: 6

expected values file: bpr3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

       1         1
       2         4
       1         5,  9, 12, 13, 15, 19, 22, 23, 29, 30, 31
       1        34, 36, 39, 41, 47, 49, 50, 51, 53, 58, 60
       1        62, 63, 68, 69, 74, 75, 76, 79, 81, 83, 86
       1        88, 91
       2        92
       1        93, 96, 99,101,102,106,109,110,112,114,117
       1       118,121,124,128,129,131,132,137,140,144,146
       1       149,150,153,154,155,159,163,164,165,167,173
       1       176,178,179,183,185,188,190,193,194,197,199
       1       203,204,209,210,214,216,217,220,221,223,224
       1       225,233,234,236,238,243,245,248,250,254,255
       1       258,259,264,266,268,269,271,273,274,275,284
       1       286,289,290,294,295,296,299
number correct: 178, total input: 300, per cent correct: 59.3

****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 15:50:16 1989   *****
****************************************

network type: 6

expected values file: bpr4.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image
```

```
      1          1,  3,  6,  7, 12, 14, 17, 20, 21, 23, 27
      1         28, 31, 36, 37, 38, 42, 47, 48, 50, 53, 56
      1         57, 60, 61, 62, 63, 68, 72, 77, 78, 79, 81
      1         83, 85, 89, 95, 98, 99,100,101,104
      2        106
      1        108,111,112,116,120,121,122,124
      2        128
      1        131,132,134,138,142,143,146,149,151,155,158
      1        160,161,162,167,170,171,173,175,178,182,183
      1        187
      2        190
      1        192,196,197,200,202,204,206
      2        209
      1        210,215,216,217,219,221,225,227
      2        230
      1        232,235,238,240,241,245,246,249,254,256,257
      2        260
      1        262,263,267,268,273,276,278,279,282,283,288
      1        289,293,295,297,300
number correct: 179, total input: 300, per cent correct: 59.7
```

(b) Results after 19318 Learning Trials

```
****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 16:27:18 1989   *****
****************************************

network type: 6

expected values file: bp1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

      1          4,  5,  6,  7, 11, 12, 14, 18, 21, 22, 23
      1         26, 31, 34, 38, 40, 44, 45, 46, 47, 54, 57
      1         58, 59, 61, 63, 65, 68, 72, 76, 77, 78, 81
      1         82, 89, 90, 93, 95, 96, 97,101,103,109,110
      1        111,112,118,119,127,128,129,130,131,133,134
      1        136,141,142,145,146,151,156,157,158,161,164
      1        167,170,171,173,175,176,184,185,188,190,191
      1        194,196,198,204,206,207,209,211,216,217,218
      1        222,223,229,230,231,232,233,236,245,247,248
      1        250,253,255,256,260,262,264,268,269,274,276
      1        279,280,282,283,284,290,291,293,297,299
number correct: 180, total input: 300, per cent correct: 60.0

****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 16:29:28 1989   *****
****************************************

network type: 6

expected values file: bpr1.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

      1          2,  5,  8,  9, 12, 15, 18, 19, 21, 22, 24
      1         25, 31, 33, 35, 38, 41, 42, 47, 49, 52, 53
```

```
        1        58, 59, 63, 64, 66, 68, 71, 75, 78, 80, 82
        1        85, 89, 90, 93, 95, 98,100,102,104,105,110
        1       111,112,115,118,121,125,127,128,136,137,138
        1       140,142,143,144,145,156,157,158,159,161,163
        1       166,167,172,173,174,178,181,182,184,190,191
        1       193,195,199,201,203,205,210,211,213,215,219
        1       223,224,226,228,232,235,236,237,241,242,245
        1       246,251,255,256,258,261,263,267,268,274,277
        1       278,279,283,285,287,290,291,292,294,297
number correct: 180, total input: 300, per cent correct: 60.0

****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 16:31:30 1989   *****
****************************************

network type: 6

expected values file: bpr2.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

        1         1,  6,  7, 10, 13, 18, 19, 20, 22, 23, 24
        1        25, 31, 33, 39, 40, 42, 43, 48, 50, 53, 56
        1        58, 60, 64, 65, 67, 69, 72, 74, 77, 78, 82
        1        84, 85, 88, 90, 91, 92, 94, 95,103,105,107
        1       108,111,115,116,119,123,124,126,130,131,135
        1       139,140,145,147,149,150,153,157,158,160,162
        1       163,165,167,171,172,176,178,180,181,185,186
        1       187,192,193,195,199,204,207,208,210,214,216
        1       218,220,223,225,229,230,232,234,235,239,242
        1       245,249,250,256,257,259,260,264,265,266,267
        1       276,277,278,280,281,282,285,288,291,294,295
        1       296
number correct: 178, total input: 300, per cent correct: 59.3

****************************************
*****        Data Comparison       *****
*****   Mon Dec 18 16:33:26 1989   *****
****************************************

network type: 6

expected values file: bpr3.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

        1         1
        2         4
        1         5,  9, 12, 13, 15, 19, 22, 23, 29, 30, 31
        1        34, 36, 39, 41, 47, 49, 50, 51, 53, 58, 60
        1        62, 63, 68, 69, 74, 75, 76, 79, 81, 83, 86
        1        88, 91, 92, 93, 96, 99,102,106,109,110,112
        1       114,117,118,121,124,128,129,131,132,137,140
        1       144,146,149,150,153,154,155,159,163,164,165
        1       167,173,176,178,179,183,185,188,190,193,194
        1       197,199,203,204,209,210,214,216,217,220,221
        1       223,224,225,233,234,236,238,243,245,248,250
        1       254,255,258,259,264,266,268,269,271,273,274
        1       275,284,286,289,290,294,295,296,299
```

```
number correct: 179, total input: 300, per cent correct: 59.7

****************************************
*****         Data Comparison      *****
*****   Mon Dec 18 16:35:28 1989   *****
****************************************

network type: 6

expected values file: bpr4.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

      1          1,  3,  6,  7, 12, 14, 17, 20, 21, 23, 27
      1         28, 31, 36, 37, 38, 42, 47, 48, 50, 53, 56
      1         57, 60, 61, 62, 63, 68, 72, 77, 78, 79
      2         80
      1         81, 83, 85, 89, 95, 98, 99
      2        100
      1        101,104
      2        106
      1        108,111,112,116,120,121,122,124,128,131,132
      1        134,138,142,143,146,149,151,155,158,160,161
      1        162,167,170,171,173,175,178,182,183,187,190
      1        192,196,197,200,202,204,206,210,215,216,217
      1        219,221,225,227
      2        230
      1        232,235,238,240,241,245,246,249,254,256,257
      2        260
      1        262,263,267,268,273,276,278,279,282,283,288
      1        289,293,295,297,300
number correct: 179, total input: 300, per cent correct: 59.7
```

D.9 Neural Network Performance with Translated, Scaled, etc. Images

D.9.1 Data Generation and Test Results Logs

(a) Adaline Network with Random Training

```
****************************************
*****        Data Generation      *****
*****  Wed Dec 20 15:38:48 1989   *****
****************************************

network type: 1

input file: image1
   images:    10   rows:     6   columns:    27   classes:    10
output file: adaline.nni

binary: no                bipolar: yes
continuous: no            training required: yes
randomize records: yes

random seed:     9910
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 1

data set number     order of images in data set

    0              0  2  1  5  7  9  6  3  8  4

****************************************
*****       Data Comparison       *****
*****  Wed Dec 20 15:41:48 1989   *****
****************************************

network type: 1

expected values file: adaline.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      1         1
      4         2
      1         3
      2         4
      1         5,  6,  7,  9, 10
number correct: 1, total input: 10, per cent correct: 10.0

****************************************
*****        Data Generation      *****
```

D. TRANSLATED, SCALED DATA LOGS D.

```
*****   Wed Dec 20 15:42:24 1989   *****
****************************************

network type: 1

input file: image2
   images:    2  rows:    6  columns:   27  classes:   10
output file: adaline.nni

binary: no              bipolar: yes
continuous: no          training required: yes
randomize records: yes

random seed:     9910
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 1

data set number      order of images in data set

     0             0  1

****************************************
*****        Data Comparison       *****
*****   Wed Dec 20 15:43:26 1989   *****
****************************************

network type: 1

expected values file: adaline.nni
actual values file: adaline.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      1         1, 2
number correct: 0, total input: 2, per cent correct:  0.0
```

(b) Hamming Network

```
****************************************
*****        Data Generation       *****
*****   Wed Dec 20 16:21:54 1989   *****
****************************************

network type: 5

input file: image1
   images:   10  rows:    6  columns:   27  classes:   10
output file: hamming.nni

binary: no              bipolar: yes
continuous: no          training required: yes
randomize records: no
```

D. TRANSLATED, SCALED DATA LOGS D.

```
random seed:         0
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 1

data set number      order of images in data set

    0            0   1   2   3   4   5   6   7   8   9

****************************************
*****       Data Comparison       *****
*****   Wed Dec 20 16:24:22 1989   *****
****************************************

network type: 5

expected values file: hamming.nni
actual values file: hamming.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      2         3,  6,  8,  9
number correct: 6, total input: 10, per cent correct: 60.0

****************************************
*****       Data Generation       *****
*****   Wed Dec 20 16:24:50 1989   *****
****************************************

network type: 5

input file: image2
   images:     2   rows:     6   columns:    27   classes:    10
output file: hamming.nni

binary: no              bipolar: yes
continuous: no          training required: yes
randomize records: no

random seed:         0
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 4
level:   1, low value: 00.00, high value: 005.0
level:   2, low value: 05.00, high value: 00010
level:   3, low value: 10.00, high value: 00015
level:   4, low value: 15.00, high value: 1.0e+21

number of data sets generated: 1
```

D. TRANSLATED, SCALED DATA LOGS D.

```
data set number      order of images in data set

    0             0  1

****************************************
*****        Data Comparison       *****
*****   Wed Dec 20 16:26:44 1989   *****
****************************************

network type: 5

expected values file: hamming.nni
actual values file: hamming.nno

error tolerance during comparison: 0.000000

Number of Errors  Record Number
  per Image

      2         2
number correct: 1, total input: 2, per cent correct: 50.0
```

(c) Recirculation Network

```
****************************************
*****        Data Generation       *****
*****   Thu Dec 21 10:51:14 1989   *****
****************************************

network type: 7

input file: imaget
   images:    10   rows:     6   columns:    27   classes:     10
output file: recirc.nni

binary: no                  bipolar: no
continuous: yes             training required: yes
randomize records: yes

random seed:     9910
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 1

data set number      order of images in data set

    0             0   2   1   5   7   9   6   3   8   4

****************************************
*****        Data Comparison       *****
*****   Thu Dec 21 10:54:24 1989   *****
****************************************

network type: 7

expected values file: recirc.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000
```

D. TRANSLATED, SCALED DATA LOGS D.

```
Number of Errors  Record Number
  per Image

      10          1
      24          2
      18          3
      24          4
      30          5
      21          6
      18          7
      12          8
      14          9
      18         10
number correct: 0, total input: 10, per cent correct:  0.0

****************************************
*****        Data Generation       *****
*****   Thu Dec 21 10:59:44 1989   *****
****************************************

network type: 7

input file: image2
   images:     2  rows:     6  columns:    27  classes:    10
output file: recirc.nni

binary: no                bipolar: no
continuous: yes           training required: yes
randomize records: yes

random seed:      9910
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 1

data set number      order of images in data set

     0             0  1

****************************************
*****        Data Comparison       *****
*****   Thu Dec 21 11:02:24 1989   *****
****************************************

network type: 7

expected values file: recirc.nni
actual values file: recirc.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

      10          1
      11          2
number correct: 0, total input: 2, per cent correct:  0.0
```

(d) Back Propagation Network

```
****************************************
```

D. TRANSLATED, SCALED DATA LOGS D.

```
*****        Data Generation        *****
*****   Wed Dec 20 15:29:52 1989    *****
*****************************************

network type: 6

input file: image1
   images:    10  rows:     6  columns:    27  classes:    10
output file: bkpstd.nni

binary: no                bipolar: no
continuous: yes           training required: yes
randomize records: yes

random seed:     9910
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 1

data set number      order of images in data set

    0             0  2  1  5  7  9  6  3  8  4

*****************************************
*****        Data Comparison        *****
*****   Wed Dec 20 15:32:30 1989    *****
*****************************************

network type: 6

expected values file: bkpstd.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

      1         2,  3,  4
      2         5
      1         6,  7
      3         9
      1         10
number correct: 2, total input: 10, per cent correct: 20.0

*****************************************
*****        Data Generation        *****
*****   Wed Dec 20 15:34:06 1989    *****
*****************************************

network type: 6

input file: image2
   images:     2  rows:     6  columns:    27  classes:    10
output file: bkpstd.nni

binary: no                bipolar: no
continuous: yes           training required: yes
randomize records: yes

random seed:     9910
```

```
number of pixels to randomize in peaks: 0, total pixels: 162
pixel scale factor: 1.000000
noise_level: 0.000000 (0 means noise not added to image)

data minimum (or adjusted minimum): 0.000000
data maximum (or adjusted maximum): 20.000000

number of pixel levels: 0

number of data sets generated: 1

data set number     order of images in data set

     0              0   1

****************************************
*****        Data Comparison      *****
*****  Wed Dec 20 15:34:54 1989   *****
****************************************

network type: 6

expected values file: bkpstd.nni
actual values file: bkpstd.nno

error tolerance during comparison: 0.310000

Number of Errors  Record Number
  per Image

     1          1,  2
number correct: 0, total input: 2, per cent correct:  0.0
```

E. PROGRAM LISTINGS E.

E.1 Program Listings

This section contains program listings for the data creation program ("nnimag") and the results analysis program ("nnres").

These programs use a header file called PSTRUC.H. This file contains pre-processor directives that allow C code to be written as structured English pseudocode and compiled directly.

These programs were compiled using the AZTEC C compiler from MANX Software.

FILENAME: pstruc.h Fri Dec 29

```
/* system constants   */
#define   YES   1                /*  constant yes */
#define   NO    0

/*  Logical Operators */
#define  AND  &&
#define   OR  ||
#define  NOT   !
#define   EQ  ==
#define   NE  !=
#define   LT   <
#define   LE  <=
#define   GT   >
#define   GE  >=

/* Branching Constructs */
#define  IF      if
#define  THEN  {
#define  ELSE  } else {
#define  ENDIF  }

#define  WHILE(e)   while (e) {
#define  ENDWHILE  }

#define  FOR(e)   for (e) {
#define  ENDFOR  }

#define  BEGIN   {
#define  END     }
```

```
/*
****************************************************************

     Program Name:  NNIMAG.C

     Purpose:  This program reads a simulated image file and
               creates an output file which can be input to
               the Neuralware software package.

     Author:  W. E. Thorp

     Date:  November 15, 1989

     Description:  The user is prompted for various control
                   parameters including network type.  The
                   file containing the image data is then input.
                   The maximum and minimum of the data is
                   calculated and saved.  The output data sets
                   are created as follows:
                   - an image is selected from the data input
                     (the selection is either sequential or random)
                   - this image is copied to a temporary array
                   - if noise is to be added, the pixels in
                     the temporary array are modified.  The pixels
                     to be modified are selected at random and changed
                     by a random amount
                   - if the output is for a binary or bipolar network
                     then each output pixel is converted into
                     several elements and written out to the file.
                   - if the output is for a continuous network
                     then each output pixel is converted to the
                     range 0 to 1 and written out to the file
                   - if using a heteroassociative network, then
                     a desired result is also output.

                 The classes are assumed to be numbered sequentially,
                 beginning with one.

                 The input file is has a header record and one or
                 more image files.  Each image file consists of
                 the class the image belongs to followed by the
                 image pixels.  The file layout is as follows:
                 - header record fields:
                    -- number of images in file
                    -- number of rows per image
                    -- number of columns per image
                    -- number of classes
                 - image data:
                    -- class number to which image belongs
                    -- image pixels
                 The output file format depends on the network
                 type.  The general formats are described in
                 the neuralware software documentation.

****************************************************************
*/
```

```
/**/
#include "stdio.h"
#include "pstruc.h"
#include "math.h"
#define low_network_type 1
#define high_network_type 7
#define no 0
#define yes 1
#define max_classes 10
#define max_images 10
#define max_rows 16
#define max_cols 64
#define max_pixel_value_ranges 10
#define max_el_per_line 8

/*
      VARIABLES
*/
int debug;
int network_type, int_reply, binary, bipolar, continuous;
int randomize_records, vector_index;
int num_images, num_rows, num_cols, num_pixels, num_pixels_to_randomize;
int num_data_sets,num_classes, num_classes_to_randomize,num_pixel_value_ranges;
int in_file_error;
int i,j,k,l,m,m1,n;
int plot_data, plot_bin, plot_this_set;
int image_index, image_selected[max_images];
int pixel_index, pixel_selected[max_rows*max_cols];
int pixels_per_line,el_per_line, training_required;
int orig_pixels [max_cols*max_rows], rand_pixels [max_cols*max_rows];
int add_random_noise;
long irand, timloc;

char *fd_in_address, *fd_out_address, in_file_name[80], out_file_name[80];
char time_str[30], *fd_log_address;
char *desired_out_char;

FILE *fp,*fplog;

float input_class[max_images];
float input_pixels [max_images][max_rows][max_cols];
float pixel_scale_factor, max_data, min_data;
float max_row_data, min_row_data, noise_level;
float off_value, desired_off_value, desired_out;
float pixel_range [max_pixel_value_ranges+1], pixel_range_size;
float out_pixels [max_cols*max_rows];
float scaley;

float rand_num, rand_index;

/*
        PROCEDURES
*/
int select_network(), rd_file(), get_rand_parameters();
int find_data_range(), randomize(),non_cont_out(), cont_out();
int plot3d();

/*
        FUNCTIONS
*/
```

```

int select_randomly(), threed();
float min(),max();
float uni();
char *ctime(),*strncpy();

```

```
/**/
main ()
BEGIN
debug = 5;
printf ("enter debug value (0 <= debug < = 5)\n");
scanf ("%d%",&debug);
select_network();
rd_file();
IF (in_file_error EQ no)
THEN
   get_rand_parameters();
   find_data_range();
   fp = fopen(fd_out_address,"w");
   IF (fp EQ NULL)
   THEN
      printf ("couldn't open output file: %s",out_file_name);
   ELSE
      printf ("do you wish to plot the image data (0 = no, 1 = yes)");
      scanf ("%d", &plot_data);
      IF (plot_data EQ yes)
      THEN
         plot_bin = no;
         IF (binary EQ yes OR bipolar EQ yes)
         THEN
            printf("plot actual quantized output data (0 = no, 1 = yes)\n");
            scanf ("%d",&plot_bin);
         ENDIF
      ENDIF
      log_run();
      fprintf(fplog,"\n\ndata set number      order of images in data set\n");
      FOR (i=0;i<num_data_sets;i++)
         IF (plot_data EQ yes)
         THEN
            printf("\n plot images for data set %d\n",i);
            printf(" (0 = no, 1 = yes, 2 = stop plotting)\n");
            scanf ("%d", &int_reply);
            IF (int_reply EQ 2)
            THEN
               plot_data = no;
               plot_this_set = no;
            ELSE
               plot_this_set = int_reply;
            ENDIF
         ENDIF
         fprintf(fplog,"\n   %3d          ",i);
         FOR (j=0;j<num_images;j++)
            image_selected[j] = no;
         ENDFOR
         FOR (j=0;j<num_images;j++)
            randomize();
            IF (binary EQ yes OR bipolar EQ yes)
            THEN
               non_cont_out();
            ELSE
               cont_out();
            ENDIF
         ENDFOR
      ENDFOR
      fclose(fp);
   ENDIF
   fclose(fplog);
ENDIF
printf ("%c",'\007');
END

```

```
/**/
/*
****************************************************************
     PROCEDURE:  select_network
****************************************************************
*/
int select_network()
BEGIN
network_type = -1;
WHILE (network_type EQ -1)
   printf("select network type\n");
   printf("\n Binary/Bipolar Inputs\n\n");
   printf("   1.  Adaline (heteroassociative)\n");
   printf("   2.  BSB Hebb (autoassociative)\n");
   printf("   3.  BSB Widrow-Hoff (autoassociative)\n");
   printf("   4.  BAM (heteroassociative)\n");
   printf("   5.  Hamming (heteroassociative)\n");
   printf("\n Continuous Inputs\n\n");
   printf("   6.  Back Propagation (heteroassociative)\n");
   printf("   7.  Recirculation (autoassociative)\n");
   printf("\nEnter choice (1-7)\n");
   scanf("%d",&int_reply);
   IF (low_network_type LE int_reply AND int_reply LE high_network_type)
   THEN
      network_type = int_reply;
   ENDIF
ENDWHILE
binary = no;
bipolar = no;
continuous = no;
num_pixels_to_randomize = 0;
pixel_scale_factor = 1.0;
off_value = -1.0;
desired_off_value = -1.0;
num_classes_to_randomize = 0;
randomize_records = no;
training_required = yes;
desired_out_char = "d";
switch (network_type)
   {
   case 1:                                                                /* Adaline */
           bipolar = yes;
           randomize_records = yes;
           num_data_sets = 30;
           fd_in_address = "image";
           fd_out_address = "adaline.nni";
           fd_log_address = "adaline.log";
           num_pixel_value_ranges = 4;
           break;
   case 2:                                                                /* BSB Hebb */
           bipolar = yes;
           randomize_records = yes;
           num_data_sets = 30;
           fd_in_address = "image";
           fd_out_address = "bsbhebb.nni";
           fd_log_address = "bsbhebb.log";
           num_pixel_value_ranges = 4;
           break;
   case 3:                                                                /* BSB Widrow Hoff */
           bipolar = yes;
```

```
            randomize_records = yes;
            num_data_sets = 30;
            fd_in_address = "image";
            fd_out_address = "bsbwh.nni";
            fd_log_address = "bsbws.log";
            num_pixel_value_ranges = 4;
            break;
    case 4:                                                                              /* BAM */
            bipolar = yes;
            randomize_records = no;
            num_data_sets = 1;
            printf("generate training data set (0 = no, 1 = yes)\n");
            printf("no response causes generation of test data sets\n");
            scanf("%d",&int_reply);
            IF (int_reply EQ no)
            THEN
               randomize_records = yes;
               num_data_sets = 30;
            ENDIF
            fd_in_address = "image";
            fd_out_address = "bam.nni";
            fd_log_address = "bam.log";
            num_pixel_value_ranges = 4;
            desired_out_char = "i";
            break;
    case 5:                                                                              /* Hamming */
            bipolar = yes;
            randomize_records = no;
            num_data_sets = 1;
            printf("generate training data set (0 = no, 1 = yes)\n");
            printf("no response causes generation of test data sets\n");
            scanf("%d",&int_reply);
            IF (int_reply EQ no)
            THEN
               randomize_records = yes;
               num_data_sets = 30;
            ENDIF
            desired_off_value = 0.0;
            fd_in_address = "image";
            fd_out_address = "hamming.nni";
            fd_log_address = "hamming.log";
            num_pixel_value_ranges = 4;
            break;
    case 6:
            continuous = yes;                                            /* Back Propagation */
            randomize_records = yes;
            num_data_sets = 30;
            fd_in_address = "image";
            fd_out_address = "bkpstd.nni";
            fd_log_address = "bkpstd.log";
            off_value = 0.0;
            desired_off_value = 0.0;
            break;
    case 7:
            continuous = yes;                                            /* Recirculation */
            randomize_records = yes;
            num_data_sets = 30;
            fd_in_address = "image";
            fd_out_address = "recirc.nni";
            fd_log_address = "recirc.log";
```

```
           off_value = 0.0;
           desired_off_value = 0.0;
           break;
   }
END
```

```
/**/
/*
****************************************************************
      PROCEDURE:  read input file
****************************************************************
*/
int rd_file()
BEGIN
printf ("enter input file name\n");
printf ("   0 = %s\n",fd_in_address);
printf ("   1 = user entered name\n");
scanf ("%d",&int_reply);
IF (int_reply NE 0)
THEN
   printf("enter name of input image file\n");
   scanf ("%s",in_file_name);
   fd_in_address = in_file_name;
ENDIF
fp = fopen (fd_in_address,"r");
in_file_error = no;
IF (fp EQ NULL)
THEN
   printf ("error opening file: %s\n",fd_in_address);
   in_file_error = yes;
ELSE
   fscanf (fp,"%d %d %d %d",
      &num_images,&num_rows,&num_cols,&num_classes);
   num_pixels = num_rows*num_cols;
   IF (num_images LE max_images AND num_rows LE max_rows
      AND num_cols LE max_cols AND num_classes LE max_classes)
   THEN
      FOR (i=0;i<num_images;i++)
         fscanf (fp,"%f",&input_class[i]);
         FOR (j=0;j<num_rows;j++)
            FOR (k=0;k<num_cols;k++)
               fscanf (fp,"%f",&input_pixels [i][j][k]);
            ENDFOR
         ENDFOR
      ENDFOR
      IF (5 LE debug)
      THEN
         FOR (i=0;i<num_images;i++)
            printf ("class = %f\n",input_class[i]);
            FOR (j=0;j<num_rows;j++)
               FOR (k=0;k<num_cols;k++)
                  printf ("image = %3d, row = %3d, col = %3d, pixel = %f\n",
                     i, j, k, input_pixels [i][j][k]);
               ENDFOR
            ENDFOR
         ENDFOR
      ENDIF
   ELSE
      printf ("value in image file exceeds program limits\n");
      printf ("   value from image file      allowed range\n");
      printf ("   images:%5d              0 to %5d\n",
         num_images,max_images);
      printf ("   rows:  %5d              0 to %5d\n",
         num_rows, max_rows);
      printf ("   cols:  %5d              0 to %5d\n",
         num_cols, max_cols);
      printf ("   classes:  %5d              0 to %5d\n",
         num_classes, max_classes);
      in_file_error = yes;
   ENDIF
   fclose(fp);
ENDIF
END
```

```
/**/
/*
*******************************************************************
      PROCEDURE:  get random parameters
*******************************************************************
*/
int get_rand_parameters()
BEGIN
printf ("add random peaks to image\n");
printf ("0 = no, 1 = yes\n");
scanf ("%d",&int_reply);
IF (int_reply NE 0)
THEN
   num_pixels_to_randomize = num_pixels + 1;
   WHILE (num_pixels_to_randomize GT num_pixels OR
      num_pixels_to_randomize LT 0)
      printf ("enter number of pixels to randomize\n");
      printf ("value entered must be between 0 and %d\n",num_pixels);
      scanf ("%d",&num_pixels_to_randomize);
   ENDWHILE
   printf ("input pixel scale factor as floating point number\n");
   printf ("pixels are randomized to be in range\n");
   printf ("0 <= new pixel value <= \n");
   printf ("   (old pixel value)*(pixel scale factor)*(random number)\n");
   scanf ("%f",&pixel_scale_factor);
ENDIF
printf ("\nadd random noise to image\n");
printf ("0 = no, 1 = yes\n");
scanf ("%d",&int_reply);
add_random_noise = no;
IF (int_reply EQ yes)
THEN
   add_random_noise = yes;
   printf("\nAll pixels equal to the minimum data value are changed\n");
   printf(" 0 <= new pixel value <= (noise level)*(random number)\n");
   printf("enter noise level as a floating point number\n");
   scanf ("%f",&noise_level);
ENDIF
IF (network_type EQ 4 AND randomize_records EQ yes)
THEN
   num_classes_to_randomize = num_classes + 1;
   WHILE (num_classes_to_randomize GT num_classes OR
      num_classes_to_randomize LT 0)
      printf ("enter number of classes to randomize\n");
      printf ("value entered must be between 0 and %d\n",num_classes);
      scanf ("%d",&num_classes_to_randomize);
   ENDWHILE
ENDIF
IF (add_random_noise EQ yes OR num_pixels_to_randomize GT 0 OR
    num_classes_to_randomize GT 0 OR randomize_records EQ yes)
THEN
   printf ("enter seed for random number generator (integer <= 10000)\n");
   scanf ("%ld",&irand);
/*
   initialize random number generator
*/
   rand_num = uni(irand);
ENDIF
END
```

```
/**/
/*
******************************************************************
      PROCEDURE:  find data range
******************************************************************
*/
int find_data_range()
BEGIN
max_data = -10.0e20;
min_data = 10.0e20;
FOR (i=0;i<num_images;i++)
   FOR (j=0;j<num_rows;j++)
      max_row_data = max(num_cols,&input_pixels[i][j][0]);
      IF (max_row_data GT max_data)
      THEN
         max_data = max_row_data;
      ENDIF
      min_row_data = min(num_cols,&input_pixels[i][j][0]);
      IF (min_row_data LT min_data)
      THEN
         min_data = min_row_data;
      ENDIF
   ENDFOR
ENDFOR
printf ("\n *****WARNING:  To provide a consistent basis for training and ");
printf ("\n testing, data sets for a particular network should use the same");
printf ("\n minimum and maximum values.  Thus, if the minimum and/or ");
printf ("\n maximum are adjusted, the adjusted values should be used ");
printf ("\n when creating all training and testing data sets for the ");
printf ("\n particular network.\n\n");
printf("data minimum = %10.3f, maximum = %10.3f\n",min_data,max_data);
printf("do you wish to adjust these values (0 = no, 1 = yes)\n");
scanf ("%d",&int_reply);
IF (int_reply NE 0)
THEN
   printf ("enter new min and max values as floating point numbers:\n");
   scanf ("%f %f",&min_data, &max_data);
   printf ("adjusted min = %10.3f, max = %10.3f\n",min_data, max_data);
ENDIF
pixel_range_size = (max_data-min_data)/num_pixel_value_ranges;
FOR (i=0;i<num_pixel_value_ranges+1;i++)
   pixel_range [i] = min_data + i*pixel_range_size;
ENDFOR
/* force first element to be zero and last element to be greater than
   any element to cover expanded ranges IF maximum and minimum adjusted
*/
pixel_range[0] = 0.0;
pixel_range[num_pixel_value_ranges] = 10.0e20;
END
```

```
/**/
/*
****************************************************************
      PROCEDURE:  log parameters from this run
****************************************************************
*/
int log_run()
BEGIN
fplog = fopen(fd_log_address,"a");
IF (fplog EQ NULL)
THEN
   printf("error opening log file: %s\n", fd_log_address);
ELSE
   time(&timloc);
   fprintf(fplog,"\n****************************************\n");
   fprintf(fplog,"*****        Data Generation       *****\n");
   strncpy(&time_str,ctime(&timloc),24);
   fprintf(fplog,"*****   %24s   *****\n",time_str);
   fprintf(fplog,"****************************************\n\n");
   fprintf(fplog,"network type: %d\n\n",network_type);
   fprintf(fplog,"input file: %s\n",fd_in_address);
   fprintf(fplog,"  images: %5d   rows: %5d   columns: %5d   classes: %5d\n",
      num_images, num_rows, num_cols, num_classes);
   fprintf(fplog,"output file: %s\n\n",fd_out_address);
   fprintf(fplog,"binary: %s",(binary ? "yes" : "no "));
   fprintf(fplog,"                 bipolar: %s\n",(bipolar ? "yes" : "no "));
   fprintf(fplog,"continuous: %s",(continuous ? "yes" : "no "));
   fprintf(fplog,"          training required: %s\n",
      (training_required ? "yes" : "no"));
   fprintf(fplog,"randomize records: %s\n\n",
      (randomize_records ? "yes" : "no"));
   fprintf(fplog,"random seed: %8ld\n",irand);
   fprintf(fplog,"number of pixels to randomize in peaks: %d, ",
      num_pixels_to_randomize);
   fprintf(fplog,"total pixels: %d\n", num_pixels);
   fprintf(fplog,"pixel scale factor: %f\n",pixel_scale_factor);
   fprintf(fplog,"noise_level: %f (0 means noise not added to image)\n\n",
      noise_level);
   IF (network_type EQ 4)
   THEN
      fprintf(fplog,"number of classes to randomize: %d\n",
         num_classes_to_randomize);
   ENDIF
   fprintf(fplog,"data minimum (or adjusted minimum): %f\n",min_data);
   fprintf(fplog,"data maximum (or adjusted maximum): %f\n\n",max_data);
   fprintf(fplog,"number of pixel levels: %d\n",num_pixel_value_ranges);
   FOR (i=0;i<num_pixel_value_ranges;i++)
      fprintf (fplog,"level: %3d, low value: %05.2f, high value: %05.2g\n",
         i+1, pixel_range[i], pixel_range[i+1]);
   ENDFOR
   fprintf(fplog,"\nnumber of data sets generated: %d",num_data_sets);
ENDIF
END
```

```
/**/
/*
*****************************************************************
      PROCEDURE:  randomize data records and pixels
*****************************************************************
*/
int randomize()
BEGIN
image_index = j;
IF (randomize_records EQ yes)
THEN
   image_index = select_randomly (num_images,image_selected);
ENDIF
fprintf(fplog,"%3d ",image_index);
IF (5 LE debug)
THEN
   printf ("image index = %d\n",image_index);
ENDIF
k = 0;
FOR (l=0;l<num_rows;l++)
   FOR (m=0;m<num_cols;m++)
      out_pixels[k]=input_pixels[image_index] [l] [m];
      k = k + 1;
   ENDFOR
ENDFOR
IF (plot_data EQ yes AND plot_this_set EQ yes)
THEN
   scaley = 32760./max_data;
   k = 0;
   FOR (l=0;l<num_rows;l++)
      FOR (m=0;m<num_cols;m++)
         orig_pixels [k] = (int)(out_pixels [k]*scaley);
         k = k + 1;
      ENDFOR
   ENDFOR
ENDIF
IF (num_pixels_to_randomize GT 0)
THEN
   FOR (k=0;k<num_pixels;k++)
      pixel_selected [k] = no;
   ENDFOR
   FOR (k=0;k<num_pixels_to_randomize;k++)
      pixel_index = select_randomly (num_pixels,pixel_selected);
      rand_num = uni(0L);
      IF (5 LE debug)
      THEN
         printf ("pxl index = %d, old val = %f,",
            pixel_index, out_pixels [pixel_index]);
      ENDIF
      IF (out_pixels [pixel_index] LE min_data)
      THEN
         out_pixels [pixel_index] = max_data;
      ENDIF
      out_pixels [pixel_index] =
         out_pixels [pixel_index]*rand_num*pixel_scale_factor;
      IF (5 LE debug)
      THEN
         printf ("ran num = %f, new val = %f\n",
            rand_num, out_pixels [pixel_index]);
      ENDIF
   ENDFOR
ENDIF
IF (add_random_noise EQ yes)
THEN
   FOR (k=0;k<num_pixels;k++)
      IF (out_pixels [k] LE min_data)
      THEN
         rand_num = uni(0L);
         out_pixels [k] = noise_level*rand_num;
      ENDIF
      IF (5 LE debug)
      THEN
         printf ("ran num = %f, new val = %f\n",
            rand_num, out_pixels [k]);
      ENDIF
   ENDFOR
ENDIF
IF (plot_data EQ yes AND plot_this_set EQ yes AND plot_bin EQ no)
THEN
   k = 0;
   FOR (l=0;l<num_rows;l++)
      FOR (m=0;m<num_cols;m++)
         rand_pixels [k] = (int)(out_pixels [k]*scaley);
         k = k + 1;
      ENDFOR
   ENDFOR
   plot3d();
ENDIF
END
```

```
/**/
/*
***************************************************************
      PROCEDURE:  output non-continuous network data file
***************************************************************
*/
int non_cont_out()
BEGIN
el_per_line = num_pixels*num_pixel_value_ranges;
IF(num_pixels*num_pixel_value_ranges GT
   max_el_per_line)
THEN
   el_per_line = max_el_per_line;
ENDIF
pixels_per_line = el_per_line/num_pixel_value_ranges;
IF (pixels_per_line LE 0)
THEN
   pixels_per_line = 1;
ENDIF
fprintf(fp,"i ");
scaley = 32760./num_pixel_value_ranges;
n = 0;
FOR (k=0;k <= (num_pixels/pixels_per_line);k++)
   IF(k GT 0)
   THEN
      fprintf (fp,"  ");
   ENDIF
   FOR (l=0;l<pixels_per_line;l++)
      FOR (m=0;m<num_pixel_value_ranges;m++)
         IF (n LT num_pixels)
            THEN
            IF(pixel_range [m] LE out_pixels [n] AND
               out_pixels [n] LT pixel_range [m+1])
            THEN
               fprintf (fp,"1.0 ");
               rand_pixels[n] = (float)(m+1)*scaley;
            ELSE
               fprintf (fp,"%02.1f ",off_value);
            ENDIF
         ENDIF
      ENDFOR
      n = n + 1;
   ENDFOR
   fprintf (fp,"\n");
ENDFOR
IF (plot_data EQ yes AND plot_this_set EQ yes AND plot_bin EQ yes)
THEN
   plot3d();
ENDIF
IF (training_required EQ yes)
THEN
   n = 0;
   fprintf (fp,"%s ",desired_out_char);
   FOR (k=1;k <= num_classes;k++)
      IF (k EQ input_class[image_index])
      THEN
         desired_out = 1.0;
         IF (n LT num_classes_to_randomize)
         THEN
            rand_num = uni(0L);
            IF (rand_num LE .5)
            THEN
               desired_out = desired_off_value;
               n = n + 1;
            ENDIF
         ENDIF
      ELSE
         desired_out = desired_off_value;
         IF (n LT num_classes_to_randomize)
         THEN
            rand_num = uni(0L);
            IF (rand_num LE .5)
            THEN
               desired_out = 1.0;
               n = n + 1;
            ENDIF
         ENDIF
      ENDIF
      fprintf (fp,"%02.1f ",desired_out);
   ENDFOR
   fprintf (fp,"\n");
   IF (network_type EQ 4)
   THEN
      fprintf (fp,"d ");
      FOR (k=1;k <= num_classes;k++)
         IF (k EQ input_class[image_index])
         THEN
            fprintf (fp,"1.0 ");
         ELSE
            fprintf (fp,"%02.1f ",desired_off_value);
         ENDIF
      ENDFOR
      fprintf (fp,"\n");
   ENDIF
ENDIF
END
```

```
/**/
/*
******************************************************************
      PROCEDURE:  output continuous network data file
******************************************************************
*/
int cont_out()
BEGIN
el_per_line = num_pixels;
IF(num_pixels GT max_el_per_line)
THEN
   el_per_line = max_el_per_line;
ENDIF
pixels_per_line = el_per_line;
IF (pixels_per_line LE 0)
THEN
   pixels_per_line = 1;
ENDIF
fprintf(fp,"i ");
n = 0;
FOR (k=0;k <= (num_pixels/pixels_per_line);k++)
   IF(k GT 0)
   THEN
      fprintf (fp,"  ");
   ENDIF
   FOR (l=0;l<pixels_per_line;l++)
      IF (n LT num_pixels)
      THEN
         out_pixels[n] = out_pixels[n]/max_data;
         IF (out_pixels[n] GT 1.0)
         THEN
            out_pixels[n] = 1.0;
         ENDIF
         fprintf (fp,"%05.3f ",out_pixels[n]);
      ENDIF
      n = n + 1;
   ENDFOR
   fprintf (fp,"\n");
ENDFOR
IF (training_required EQ yes)
THEN
   fprintf (fp,"%s ",desired_out_char);
   IF (network_type EQ 7)
   THEN
      n = 0;
      m = 0;
      m1= 0;
      FOR (k=0;k <= (num_pixels/pixels_per_line);k++)
         IF(k GT 0)
         THEN
            fprintf (fp,"  ");
         ENDIF
         FOR (l=0;l<pixels_per_line;l++)
            IF (n LT num_pixels)
            THEN
               out_pixels[n] = input_pixels [image_index][m][m1]/max_data;
               IF (out_pixels[n] GT 1.0)
               THEN
                  out_pixels[n] = 1.0;
               ENDIF
               fprintf (fp,"%05.3f ",out_pixels[n]);
            ENDIF
            n = n + 1;
            m1 = m1 + 1;
            IF (m1 GE num_cols)
            THEN
               m1 = 0;
               m = m + 1;
            ENDIF
         ENDFOR
         fprintf (fp,"\n");
      ENDFOR
   ELSE
      FOR (k=1;k <= num_classes;k++)
         IF (k EQ input_class[image_index])
         THEN
            fprintf (fp,"1.0 ");
         ELSE
            fprintf (fp,"%02.1f ",desired_off_value);
         ENDIF
      ENDFOR
      fprintf (fp,"\n");
   ENDIF
ENDIF
END
```

```
/**/
/*
****************************************************************
      FUNCTION:  min
****************************************************************
*/
float min(num_el,array)
int num_el;
float array[];
BEGIN
int i;
float minxx;
minxx=10.0e20;
FOR (i=0;i<num_el;i++)
   IF (array[i] LT minxx)
   THEN
      minxx=array[i];
   ENDIF
   IF (5 LE debug)
   THEN
      printf ("array[%2d]=%10.2f,min=%10.2f\n",i,array[i],minxx);
   ENDIF
ENDFOR
return minxx;
END
```

```
/**/
/*
****************************************************************
      FUNCTION:  max
****************************************************************
*/
float max(num_el,array)
int num_el;
float array[];
BEGIN
int i;
float maxxx;
maxxx=-10.0e20;
FOR (i=0;i<num_el;i++)
   IF (array[i] GT maxxx)
   THEN
      maxxx=array[i];
   ENDIF
   IF (5 LE debug)
   THEN
      printf ("array[%2d]=%10.2f,max=%10.2f\n",i,array[i],maxxx);
   ENDIF
ENDFOR
return maxxx;
END
```

```
/**/
/*
*****************************************************************
        FUNCTION:  plot data and randomized data
*****************************************************************
*/
int plot3d()
BEGIN
float phi,theta;

phi=10.*.017453292;
theta=45.*.017453292;

scr_clear();
mode (6);
printf ("\n    Data set: %d, Image: %d",i, image_index);
printf ("\n          Original Image");
printf ("                         Image with Random Changes");
printf ("\nenter 0 to stop plotting, 1 to see next plot");
threeD(phi,theta,num_cols-1,num_rows-1,0,0,orig_pixels,299,199);
threeD(phi,theta,num_cols-1,num_rows-1,300,0,rand_pixels,299,199);
scanf ("%d",&plot_this_set);
mode (2);
END
```

```
/**/
/*
****************************************************************
      FUNCTION:  produce 3d plot
****************************************************************
*/
/*
      PROC:THREE D

      FUNCTION:draw a three D plot on the RGD.

      INPUT:
            phi - rotation around Y axis
            theta - rotation around X axis
            iub - column dimension of data to plot(x-axis)
            jub - row dimension of data to plot(z-axis)
            xcorn - coordinate of x corner of plot-lower left corner is (0,0)
            ycorn - coordinate of y corner of plot
            data - pointer to buffer of data to plot
            xlen - pixels per row on RGD for scaling-defines a drawing window
                   must be <= current RGD H resolution.
            ylen - rows per RGD screen for scaling-defines a drawing window
                   must be <= current RGD V resolution

      SPECIFICATIONS:

                 INCLUDED FILES:
*/
#define maxH_RGD 600
#define maxV_RGD 200
/*
                 PROCEDURE CODENAME:
*/
threeD(phi,theta,iub,jub,xcorn,ycorn,data,xlen,ylen)
float phi,theta;
int iub,jub,xcorn,ycorn,*data,xlen,ylen;
{
/*
                 EXTERNAL DECLARATIONS
*/
/*
                 INTERNAL DECLARATIONS
*/
int   mskflg,dx,dy,i,j,k,l,m,n;
float rotate[3] [3];
int row,xtran,ytran;
long fill;
double cosphi,costheta,sintheta,sinphi;
int inc;
float scalex,scaley,scalez,jzscale;
static int mask[maxH_RGD];
static int x[maxH_RGD],z[maxH_RGD];
static int xval,yval,cntmask,canmask,incy,incx,predx,predy;

/**************************************************************************/
```

```
/**/
point(xcorn,ycorn);
lineto(xcorn+xlen-1,ycorn);
lineto(xcorn+xlen-1,ycorn+ylen-1);
lineto(xcorn,ycorn+ylen-1);
lineto(xcorn,ycorn);
/* create scaling and rotation matrix */

   cosphi = cos(phi);
   costheta = cos(theta);
   sintheta = sin(theta);
   sinphi = sin(phi);

   /* scale y to use 75% of vertical screen. The data is assumed to be scaled
      in the range between 0 and 32766 by the TASP */

   scaley = ((float)ylen/32766.0) * .75;
   scalex = ((double)xlen/((cosphi * iub) + (sinphi * jub)));
   scalez = ((double)ylen/((cosphi * iub) + (sinphi * jub)));
   rotate[0][0] = cosphi * scalex;
   rotate[1][0] = sintheta * sinphi;
   rotate[0][1] = 0.0;
   rotate[1][1] = costheta * scaley;
   rotate[0][2] = - sinphi;
   rotate[1][2] = sintheta * cosphi;

   xtran = xcorn + (sinphi * jub * scalex);
   ytran = ycorn;

   /* clear the mask */

   FOR(i=0;i<maxH_RGD;i++)
      mask[i]=0;
   ENDFOR
   inc = iub+1;
   /* rotate the data */
   FOR (j = 0;j<=jub;j++)
      jzscale = j * scalez;
      FOR (i = 0;i<=iub;i++)
         x[i] = i * rotate[0][0] + jzscale * rotate[0][2];
         z[i] = (i * rotate[1][0] * scalex +  *(data+i) * rotate[1][1] +
                     jzscale * rotate[1][2]);
      ENDFOR
      dx = x[0] + xtran;
      dy = z[0] + ytran;
      point(dx,dy);
      predx= dx;
      predy = dy;
      IF(dy GE mask[dx] )
      THEN
         mskflg=1;
         mask[dx]=dy;
      ELSE
         mskflg=0;
      ENDIF
      canmask=mask[dx];
      /* draw the figure */
      FOR (i=1;i<=iub;i++)
         dx = x[i] + xtran;
         dy = z[i] + ytran;
```

```
     IF (dx LT 0)
     THEN
        dx = 0;
     ELSE
        IF (dx GT xlen + xtran)
        THEN
           IF(dx GE maxH_RGD)
           THEN
              dx = maxH_RGD-1;
           ELSE
              dx = xlen + xtran;
           ENDIF
        ENDIF
     ENDIF
     IF(dx NE predx)
     THEN
        incy = (float)(dy-predy)/(float)(dx-predx);
        yval = predy;
        for(l=predx;l<dx;l++)
           {
           if(yval GT mask[l])
              mask[l]=yval;
           yval = yval + incy;
           }
canmask=mask[dx];
    ENDIF
    IF (dy LT 0)
    THEN
       dy = 0;
    ELSE
       IF(dy GE maxV_RGD)
       THEN
          dy = maxV_RGD-1;
       ENDIF
    ENDIF
    IF (dy GE canmask)
    THEN
       canmask=dy;
IF (mskflg EQ 1)
       THEN
          lineto(dx,dy);
ELSE
          IF(dx GT predx)
          THEN
             incy = (float)(canmask-predy)/(float)(dx-predx);
             if(incy>0)
             {
                for(yval=predy;yval<mask[dx];yval=yval+incy)
                   {
                   predx++;
                   }
                mask[++predx] = yval;
             }
          ENDIF
          point(predx,mask[predx]);
          lineto(dx,canmask);
          mskflg=1;
        ENDIF
    ELSE
       IF (mskflg EQ 1)
```

```
            THEN
               IF(dx GT predx)
               THEN
                  incy = (float)(dy-predy)/(float)(dx-predx);
                  if(incy > 0)
                     {
                     for(yval=predy;yval>mask[dx];yval=yval+incy)
                        {
                        predx++;
                        }
                     }
                  mask[predx] = yval-incy;
               ENDIF
               lineto(predx,mask[predx]);
               mskflg=0;
            ENDIF
         ENDIF
         predy = dy;
         predx = dx;
      ENDFOR
      data = data + inc;
   ENDFOR
END
```

```
/**/
/*
*************************************************************
      FUNCTION:  generate uniformly distributed random number
*************************************************************
*/
/*
      UNIFORMLY DISTRIBUTED RANDOM NUMBER GENERATOR
*/
float uni(jj)
long jj;
BEGIN
static long M[129], L, MO, K, J;
static int i;
float UNI_NUM;
long IABS();

IF(jj NE 0)
THEN
   M[1]=jj;
   FOR (i=2;i<=128;i++)
      M[i]=69069*M[i-1]+1;
   ENDFOR
   L=71365*M[128];
   MO=221261*L;
   K=69069*MO+1;
ENDIF
L=71365*L+1;
J=1+IABS(L)/16777216;
MO=221261*MO+1;
UNI_NUM=.5+(float)(M[J]+L+MO)/(2*.2147483648E10);
K=69069*K+1;
M[J]=K;
return (UNI_NUM);
END
long IABS(L1)
long L1;
BEGIN
long abs;
abs = L1;
IF (abs LT 0)
THEN
   abs = -L1;
ENDIF
return (abs);
END
```

```
/*
****************************************************************

     Program Name:  NNRES.C

     Purpose:  This program compares actual Neural Network
               output with expected output.

     Author:  W. E. Thorp

     Date:  November 15, 1989

     Description:  The user is prompted for various control
                   parameters including network type.  The
                   files containing the actual and expected
                   values are opened.  Actual and expected
                   records are read one at a time and compared.
                   For binary/bipolar networks, the comparison
                   must be exact.  For continuous networks, a
                   range of values is allowed.


****************************************************************
*/
```

```
/**/
#include "stdio.h"
#include "pstruc.h"
#define no 0
#define yes 1
#define low_network_type 1
#define high_network_type 7
#define low_format 1
#define high_format 3
#define max_num_to_compare 1024
#define max_errors_per_line 11

/*
     VARIABLES
*/
int debug;
int network_type, int_reply, binary, bipolar, continuous;
int op_file_error;
int i,j,k,l,m,n;
int comp_out_format, next_exp_rec, next_act_rec;
int num_to_compare, num_matched, num_read, matched;
int err_count, prev_err_count, hdr_out, errors_on_line, off_value;

char *fd_exp_address, *fd_act_address, in_file_name[80], out_file_name[80];
char *fd_log_address;
char exp_buf[100], exp_con[5], act_buf[100], act_con[5];
char exp_char, EOF_flag;
char time_str[30];

long timloc;

FILE *fpe, *fpa, *fplog;

float exp_values[max_num_to_compare], act_values[max_num_to_compare];
float delta_err, per_cent_correct;

/*
     PROCEDURES
*/
int select_network(), op_files(), comp_files();
int get_exp_rec(), get_act_rec(), test_bin(), test_cont(), log_run();
/*
     FUNCTIONS
*/
char *ctime(),*strncpy();

```

```
/**/
main ()
BEGIN
debug = 5;
/* ***********************************
printf ("enter debug value\n");
scanf ("%d%",&debug);
************************************* */
hdr_out = no;
errors_on_line = 0;
prev_err_count = -1;
select_network();
op_file_error = no;
op_files();
IF (op_file_error EQ no)
THEN
   comp_out_format = -1;
   WHILE (comp_out_format EQ -1)
      printf("select format for comparison output\n");
      printf("   1.  output all actual and expected records\n");
      printf("   2.  output only those records that don't match\n");
      printf("   3.  output no actual or expected records\n");
      scanf("%d",&int_reply);
      IF (low_format LE int_reply AND int_reply LE high_format)
      THEN
         comp_out_format = int_reply;
      ENDIF
   ENDWHILE
   printf("enter number of elements to compare (<= %d)\n",
      max_num_to_compare);
   scanf("%d",&num_to_compare);
/* ********************************************************************
   IF (continuous EQ yes)
   THEN
      printf("enter allowed error during tests ");
      printf("for matches (in floating format)\n");
      scanf("%f",&delta_err);
   ENDIF
   ********************************************************************* */
   printf("margin for error during comparison set to %f\n",delta_err);
   printf("do you wish to change it (0 = no, 1 = yes)\n");
   scanf("%d",&int_reply);
   IF (int_reply NE no)
   THEN
      printf("enter new error in floating format\n");
      scanf ("%f",&delta_err);
   ENDIF
   log_run();
   IF (num_to_compare LE max_num_to_compare)
   THEN
      comp_files();
      fprintf(fplog,"\nnumber correct: %d, total input: %d, ",
         num_matched, num_read);
      fprintf(fplog,"per cent correct: %4.1f\n",per_cent_correct);
   ENDIF
ENDIF
fclose (fpe);
fclose (fpa);
fclose (fplog);
printf ("%c",'\007');
```

```
131:  END
```

```
/**/
/*
******************************************************************
      PROCEDURE:  select_network
******************************************************************
*/
int select_network()
BEGIN
network_type = -1;
WHILE (network_type EQ -1)
   printf("select network type\n");
   printf("\n Binary/Bipolar Inputs\n\n");
   printf("   1.  Adaline (heteroassociative)\n");
   printf("   2.  BSB Hebb (autoassociative)\n");
   printf("   3.  BSB Widrow-Hoff (autoassociative)\n");
   printf("   4.  BAM (heteroassociative)\n");
   printf("   5.  Hamming (heteroassociative)\n");
   printf("\n Continuous Inputs\n\n");
   printf("   6.  Back Propagation (heteroassociative)\n");
   printf("   7.  Recirculation (autoassociative)\n");
   printf("\nEnter choice (1-7)\n");
   scanf("%d",&int_reply);
   IF (low_network_type LE int_reply AND int_reply LE high_network_type)
   THEN
      network_type = int_reply;
   ENDIF
ENDWHILE
binary = no;
bipolar = no;
continuous = no;
off_value = -1.0;
exp_char = 'd';
delta_err = 0;
switch (network_type)
   {
   case 1:                                                                  /* Adaline */
           bipolar = yes;
           fd_exp_address = "adaline.nni";
           fd_act_address = "adaline.nno";
           fd_log_address = "adaline.log";
           break;
   case 2:                                                                  /* BSB Hebb */
           bipolar = yes;
           exp_char = 'i';
           fd_exp_address = "bsbhebb.nni";
           fd_act_address = "bsbhebb.nno";
           fd_log_address = "bsbhebb.log";
           delta_err = .31;
           break;
   case 3:                                                                  /* BSB Widrow Hoff */
           bipolar = yes;
           exp_char = 'i';
           fd_exp_address = "bsbwh.nni";
           fd_act_address = "bsbwh.nno";
           fd_log_address = "bsbws.log";
           delta_err = .31;
           break;
   case 4:                                                                  /* BAM */
           bipolar = yes;
           fd_exp_address = "bam.nni";
```

```
            fd_act_address = "bam.nno";
            fd_log_address = "bam.log";
            break;
    case 5:                                                                  /* Hamming */
            bipolar = yes;
            fd_exp_address = "hamming.nni";
            fd_act_address = "hamming.nno";
            fd_log_address = "hamming.log";
            break;
    case 6:
            continuous = yes;                                       /* Back Propagation */
            fd_exp_address = "bkpstd.nni";
            fd_act_address = "bkpstd.nno";
            fd_log_address = "bkpstd.log";
            off_value = 0.0;
            delta_err = .31;
            break;
    case 7:
            continuous = yes;                                       /* Recirculation */
            printf ("exp_char = %c, change to i (0 = no, 1 = yes)\n",exp_char);
            scanf("%d",&int_reply);
            IF (int_reply EQ 1)
            THEN
               exp_char = 'i';
            ENDIF
            fd_exp_address = "recirc.nni";
            fd_act_address = "recirc.nno";
            fd_log_address = "recirc.log";
            off_value = 0.0;
            delta_err = .31;
            break;
    }
END
```

```
/**/
/*
*****************************************************************
      PROCEDURE:  open expected and actual files
*****************************************************************
*/
int op_files()
BEGIN
printf ("enter expected file name\n");
printf ("   0 = %s\n",fd_exp_address);
printf ("   1 = user entered name\n");
scanf ("%d",&int_reply);
IF (int_reply NE 0)
THEN
   printf("enter name of file containing expected data\n");
   scanf ("%s",in_file_name);
   fd_exp_address = in_file_name;
ENDIF
fpe = fopen (fd_exp_address,"r");
IF (fpe EQ NULL)
THEN
   printf ("error opening file: %s\n",fd_exp_address);
   op_file_error = yes;
ELSE
   printf ("enter actual file name\n");
   printf ("   0 = %s\n",fd_act_address);
   printf ("   1 = user entered name\n");
   scanf ("%d",&int_reply);
   IF (int_reply NE 0)
   THEN
      printf("enter name of file containing actual data\n");
      scanf ("%s",in_file_name);
      fd_act_address = in_file_name;
   ENDIF
   fpa = fopen (fd_act_address,"r");
   IF (fpa EQ NULL)
   THEN
      printf ("error opening file: %s\n",fd_exp_address);
      op_file_error = yes;
   ENDIF
ENDIF
END
```

```
/**/
/*
*****************************************************************
      PROCEDURE:  compare files
*****************************************************************
*/
int comp_files()
BEGIN
EOF_flag = '9';
WHILE (EOF_flag NE EOF)
   get_exp_rec();
   get_act_rec();
   IF (EOF_flag NE EOF)
   THEN
      num_read = num_read + 1;
      err_count = 0;
      IF (delta_err LE 0.0)
      THEN
         test_bin();
      ELSE
         test_cont();
      ENDIF
      IF (matched EQ yes)
      THEN
         num_matched = num_matched + 1;
         IF (comp_out_format EQ 1)
         THEN
            printf ("record number: %d, exp = act\n",num_read);
         ENDIF
      ELSE
         IF (hdr_out EQ no)
         THEN
            fprintf(fplog,"Number of Errors  Record Number\n");
            fprintf(fplog,"  per Image\n");
            hdr_out = yes;
         ENDIF
         IF (prev_err_count EQ err_count)
         THEN
            IF (errors_on_line LT max_errors_per_line-1)
            THEN
               fprintf(fplog,",%3d",num_read);
               errors_on_line = errors_on_line + 1;
            ELSE
               fprintf(fplog,",%3d",num_read);
               errors_on_line = 0;
               prev_err_count = -1;
            ENDIF
         ELSE
            fprintf(fplog,"\n    %4d       %3d",err_count,num_read);
            prev_err_count = err_count;
            errors_on_line = 1;
         ENDIF
         IF (comp_out_format EQ 1 OR comp_out_format EQ 2)
         THEN
            printf ("record number: %d, exp <> act\n",num_read);
         ENDIF
      ENDIF
      IF (comp_out_format EQ 1 OR (comp_out_format EQ 2 AND matched EQ no))
      THEN
         printf("exp: ");
         FOR (i=0;i<num_to_compare;i++)
            printf("%03.2f ",exp_values[i]);
         ENDFOR
         printf("\n");
         printf("act: ");
         FOR (i=0;i<num_to_compare;i++)
/* *************************************************************
            IF (act_values[i] < 0.0)
            THEN
               act_values[i] = 0.0;
            ENDIF
   ************************************************************* */
            printf("%03.2f ",act_values[i]);
         ENDFOR
         printf("\n");
      ENDIF
   ENDIF
ENDWHILE
per_cent_correct = (float)num_matched/(float)num_read*100.;
printf ("number correct = %d, total input = %d, per cent = %4.1f\n",
   num_matched,num_read,per_cent_correct);
END
```

```
/**/
/*
*****************************************************************
      PROCEDURE:  get next expected record
*****************************************************************
*/
int get_exp_rec()
BEGIN
next_exp_rec = no;
WHILE (next_exp_rec EQ no)
   EOF_flag = fscanf(fpe,"%c",exp_con);
   IF (EOF_flag EQ EOF)
   THEN
      next_exp_rec = yes;
   ELSE
      IF (exp_con[0] EQ exp_char)
      THEN
         FOR (i=0;i<num_to_compare;i++)
            fscanf(fpe,"%f",&exp_values[i]);
         ENDFOR
         next_exp_rec = yes;
      ELSE
         fgets(exp_buf,100,fpe);
      ENDIF
   ENDIF
ENDWHILE
END
/*
*****************************************************************
      PROCEDURE:  net next actual record
*****************************************************************
*/
int get_act_rec()
BEGIN
next_act_rec = no;
WHILE (next_act_rec EQ no)
   EOF_flag = fscanf(fpa,"%c",act_con);
   IF (EOF_flag EQ EOF)
   THEN
      next_act_rec = yes;
   ELSE
      IF (act_con[0] EQ 'r')
      THEN
         FOR (i=0;i<num_to_compare;i++)
                  fscanf(fpa,"%f%c",&act_values[i],act_buf);
         ENDFOR
         next_act_rec = yes;
      ELSE
         fgets(act_buf,100,fpa);
      ENDIF
   ENDIF
ENDWHILE
END
```

```
/**/
/*
*****************************************************************
      PROCEDURE:  test data from binary/bipolar networks
*****************************************************************
*/
int test_bin()
BEGIN
matched = yes;
FOR (i=0;i<num_to_compare;i++)
   IF (exp_values[i] NE act_values[i])
   THEN
      matched = no;
      err_count = err_count + 1;
   ENDIF
ENDFOR
END
/*
*****************************************************************
      PROCEDURE:  test data from continuous networks
*****************************************************************
*/
int test_cont()
BEGIN
matched = yes;
FOR (i=0;i<num_to_compare;i++)
   IF ((act_values[i] LT (exp_values[i] - delta_err)) OR
      (act_values[i] GT (exp_values[i] + delta_err)))
   THEN
      matched = no;
      err_count = err_count + 1;
   ENDIF
ENDFOR
END
```

```
/**/
/*
**************************************************************
      PROCEDURE:  log parameters from this run
**************************************************************
*/
int log_run()
BEGIN
fplog = fopen(fd_log_address,"a");
IF (fplog EQ NULL)
THEN
   printf("error opening log file: %s\n", fd_log_address);
ELSE
   time(&timloc);
   fprintf(fplog,"\n***************************************\n");
   fprintf(fplog,"******       Data Comparison      *****\n");
   strncpy(&time_str,ctime(&timloc),24);
   fprintf(fplog,"******   %24s   *****\n",time_str);
   fprintf(fplog,"***************************************\n\n");
   fprintf(fplog,"network type: %d\n\n",network_type);
   fprintf(fplog,"expected values file: %s\n",fd_exp_address);
   fprintf(fplog,"actual values file: %s\n\n",fd_act_address);
   fprintf(fplog,"error tolerance during comparison: %f\n\n",delta_err);
ENDIF
END
```

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EVALUATION OF NEURAL NETWORK PERFORMANCE IN TARGET CLASSIFICATION APPLICATIONS (U)

4. AUTHORS (Last name, first name, middle initial)

W.E. Thorp

5. DATE OF PUBLICATION (month and year of publication of document)

December 1989

6a. NO. OF PAGES (total containing information. Include Annexes, Appendices, etc.)

259

6b. NO. OF REFS (total cited in document)

7

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

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8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

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9a. PROJECT OR GRANT NO. (if appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant)

021LA11

9b. CONTRACT NO. (if appropriate, the applicable number under which the document was written)

W7714-9-9151

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CORPORATE AUTHOR: Thorp (W E) Associates Ltd, Ottawa ONT (CAN);Defence Research Establishment Ottawa, Ottawa ONT (CAN)

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DESCRIPTORS: (U) Target acquisition;Pattern recognition;Neural nets;Computerized simulation;Radar images;Synthetic aperture radar;Ship signatures;Evaluation;Models;Target classification

REPORT DATE: 15 Dec 1989
NUMBER OF PAGES : 266

DRDKIM N°: 90-01825
CANDIS N°: 64092
Format(s): Hardcopy;Originator's fiche received by DSIS;Document Image stored on Optical Disk

Date modified: 2003-04-17 Important Notices